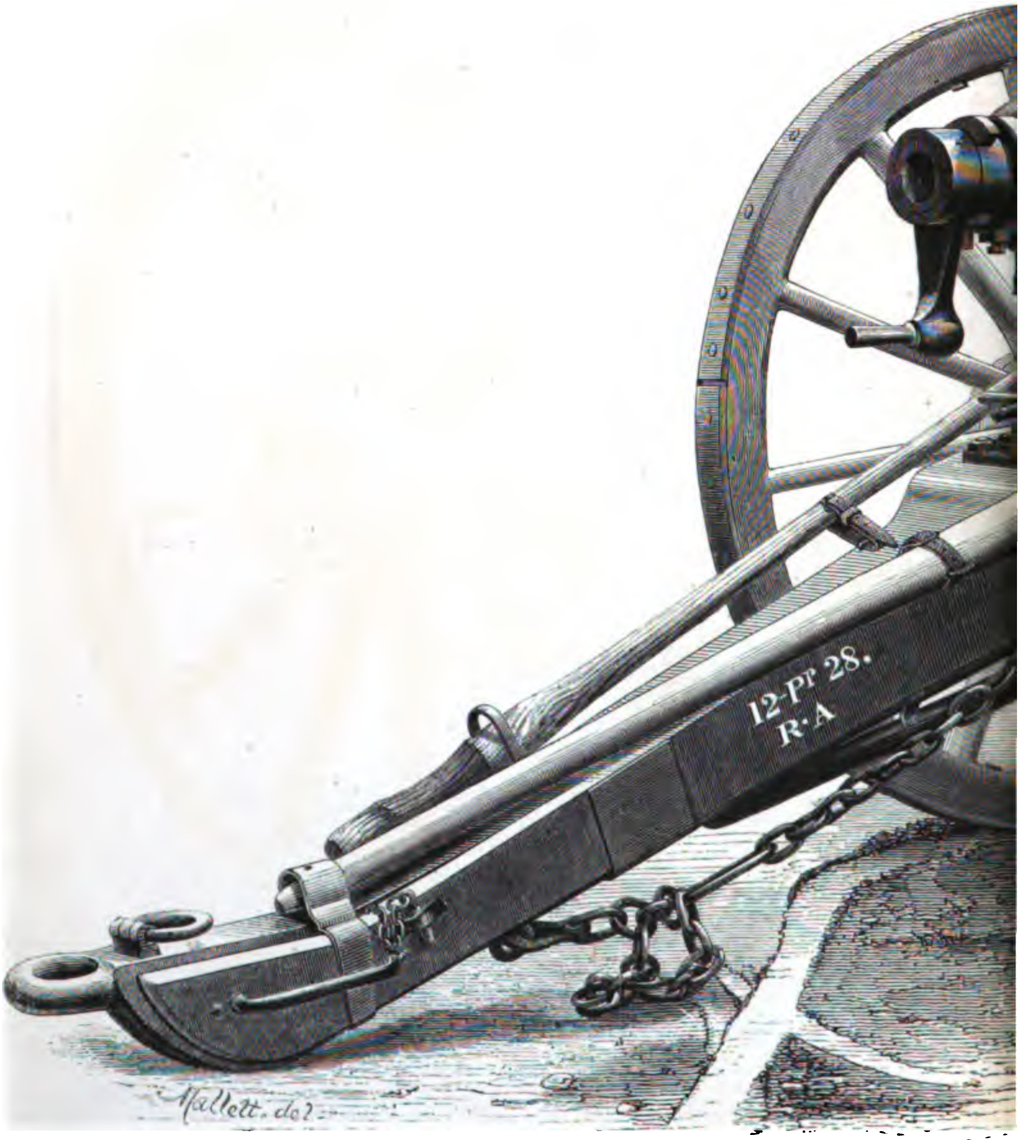

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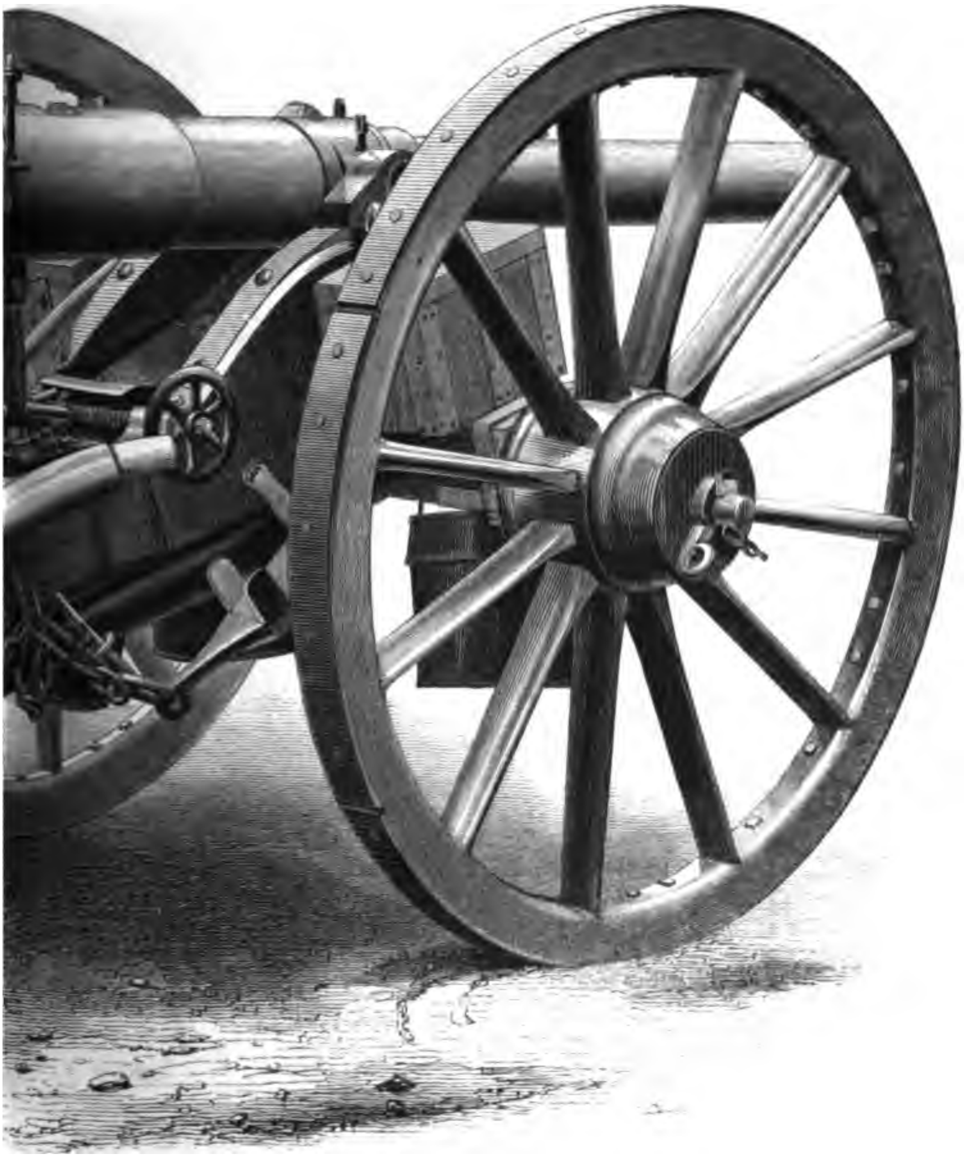

GUN AND CARRIAGE.

Anal.

THE

INDUSTRIAL RESOURCES

OF THE

DISTRICT OF THE THREE NORTHERN RIVERS,

THE TYNE, WEAR, AND TEES,

INCLUDING

THE REPORTS ON THE LOCAL MANUFACTURES,

READ BEFORE

THE BRITISH ASSOCIATION, IN 1863.

EDITED BY

William George
SIR W. G. ARMSTRONG, C.B., LL.D., F.R.S.
I. LOWTHIAN BELL, ESQ.
JOHN TAYLOR, ESQ.
DR. RICHARDSON.

WITH NOTES AND APPENDICES.

ILLUSTRATED WITH MAPS, PLANS, AND WOOD ENGRAVINGS.

SECOND EDITION.

LONDON:
LONGMAN, GREEN, LONGMAN, ROBERTS, AND GREEN.
NEWCASTLE-UPON-TYNE:
A. REID, PRINTING COURT BUILDINGS.
1864.

NEWCASTLE-UPON-TYNE:
A. REID, PRINTING COURT BUILDINGS, SIDE.

PUBLISHER'S PREFACE TO THE SECOND EDITION.

In the interval which has elapsed since the first edition of this work was published, we have been so fortunate as to secure the assistance of some gentlemen to add reports on different manufactures, which were unavoidably omitted on the former occasion. These Reports include—

The Manufacture of Carpets	By Mr. W. Henderson.
Ditto Hats	By Mr. W. Wilson.
Ditto Rope	By Mr. G. Luckley.
The Improvements of the River Wear ...	By Mr. T. Meik.

In our preface to the first edition, we were enabled to include a valuable Table of the Shipping with cargoes, outwards and inwards, of the North-Eastern Ports, for which we were indebted to the courtesy of H.M. Collectors of Customs in this district, and we have now the pleasure to give the following interesting Abstract of Shipping Registry Returns prepared by Mr. Luckley, from which it appears that the value of the shipping, owned on these three rivers, amounts to the extraordinary sum of £5,099,000.

TONNAGE AND VALUE OF THE SHIPPING OWNED ON THE TYNE, WEAR, AND TEES.

RIVER TYNE.

	No.	Tonnage.	Value.	
Newcastle—Sailing vessels	461	107,379	£680,000	
Merchant steamers ...	23	8,995	225,000	
Tugs and river craft ...	90	1,895	60,000	£965,000
	574	118,269		
Carried forward				£965,000

		No.	Tonnage.	Value.	
	Brought forward				£965,000
NORTH SHIELDS (Seaton Sluice, Blyth, Warkworth, Amble).	Sailing vessels ...	631 ...	173,460	... £1,120,000	
	Merchant steamers	2 ...	653	... 16,000	
	Tugs	130 ...	1,676	... 50,000	1,186,000
		763	175,789		
SOUTH SHIELDS—	Sailing vessels ...	314 ...	90,641	... £530,000	
	Merchant steamer ...	1 ...	169	... 4,000	
	Tugs	21 ...	400	... 15,000	549,000
		336	91,210		£2,700,000

TYNE PORTS.

		No.	Tonnage.	Value.	
Totals—	Sailing vessels ...	1406 ...	371,480	... £2,230,000	
	Merchant steamers ...	26 ...	9,817	... 245,000	
	Tugs and river craft	241 ...	3,971	... 125,000	£2,700,000
		1673	385,268		

RIVER WEAR.

		No.	Tonnage.	Value.	
SUNDERLAND (Seaham).	Sailing vessels	859 ...	210,963	... £1,443,000	
	Merchant steamers ...	29 ...	14,401	... 360,000	
	Tugs	59 ...	839	... 27,000	£1,830,000
		947	226,203		

RIVER TEES.

		No.	Tonnage.	Value.	
HARTLEPOOL—	Sailing vessels	113 ...	32,166	... £200,000	
	Merchant steamers ...	2 ...	864	... 22,000	£222,000
		115	33,030		
WEST HARTLEPOOL—	Sailing vessels	59 ...	10,333	... £60,000	
	Merchant steamers	10 ...	3,619	... 90,000	
	Tug steamers ...	4 ...	52	... 2,000	152,000
		73	14,004		
MIDDLESBRO'—	Sailing vessels	66 ...	9,836	... £52,000	
	Merchant steamers ...	5 ...	1,802	... 45,000	
	Tug steamers	13 ...	277	... 8,000	105,000
		84	11,915		
	Carried forward				£479,000

	No.		Tonnage.		Value.	
Brought forward						£479,000
STOCKTON—Sailing vessels	41	...	9,240	...	£63,000	
Merchant steamers ...	3	...	841	...	21,000	
Tug steamers	11	...	263	...	6,000	
						90,000
	55		10,344			
						£569,000

TEES PORTS.

Totals—Sailing vessels	279	...	61,575	...	£375,000	
Merchant steamers ...	20	...	7,126	...	178,000	
Tug steamers	28	...	592	...	16,000	
						£569,000
	327		69,293			

AGGREGATE TOTALS OF THE THREE RIVERS.

Tyne ports	1,673	...	385,268	...	£2,700,000
Wear ditto	947	...	226,203	...	1,830,000
Tees ditto	327	...	69,293	...	569,000
	2,947		724,864		£5,099,000

The importance of the three Northern Rivers, as regards Shipping, is apparent on comparing their Tonnage with that of the principal rivers of the Kingdom :—

	Tons.
Mersey	1,406,904
Thames	1,059,356
The Three Northern Rivers	724,864
Clyde	358,097

The additional information we have obtained, enables us to give the following more correct statement of the annual value of the Mining and Manufactured Products of the District of the Three Northern Rivers :—

ANNUAL VALUE OF THE MINING AND MANUFACTURED PRODUCTS.

Coals	£6,650,471
Metallurgical products	3,707,941
Chemical manufactures	1,583,220
Textile manufactures	972,400
Leather	135,659
Glass and clay wares	1,066,650
Iron and timber shipbuilding	2,275,828
Engines and machinery	1,928,600

We are glad to avail ourselves of this opportunity to direct attention to one important branch of manufactures for which this district has long been celebrated. The importance of the Chemical Manufactures to this locality, is daily increasing, and the discovery of the bed of Rock-salt at Middlesbro', will probably still further stimulate their growth and development.

The combined advantages of cheap and suitable fuel, chalk, building materials, &c., and low freights to all parts of the world, which are found in the Tyne, have naturally given this locality, preëminent advantages over all other ports, and led to the establishment of Chemical Factories, where about one-half of all the Chemical Products of the Kingdom, are now manufactured.

Few persons are aware of the importance of these manufactures to a locality which supplies the raw materials at a small cost, but where, by the union of scientific knowledge and manual labour, they are worked up into forms of greatly increased value and of almost universal application. It has been said, that for every 100 tons of Chemicals manufactured, employment is given to 250 tons of Shipping, and support to 30 or 40 individuals, whilst 250 tons of coal are consumed in their production. This district is a large exporting locality, and the imports of sulphur ores, salt, chalk, manganese, timber, &c., for the use of the chemical manufactures, assists in cheapening both inward and outward freights.

This volume also contains some remarkable illustrations of the benencial effects of the Free Trade Legislation of past years.

The repeal of the import duty on lead, has been followed by a large increase in the quantity of this metal imported from Spain, and at the same time, it has been accompanied by a considerable development of the lead mining of this

district. The import of this metal has also been the means of introducing a new trade, which, but for the facilities afforded by the shipments of lead, would probably never have arisen. This new trade is the import of Esparto grass from Spain, for the use of the paper-makers. This grass is a very bulky article, and could scarcely bear the cost of freight, &c., unless combined with a heavy material like pig lead.

The rapid growth of the Esparto Grass Trade is seen from the following Table of Imports, which has been kindly prepared by Mr. C. O. McAllum :—

	UNITED KINGDOM. Tons.	TYNE. Tons.
1856, 1857	463	463
1858	No import	No import
1859	192	192
1860	1,500	1,224
1861	3,115	2,618
1862	11,685	9,534
1863	22,957	18,848
1st 6 months 1864	25,786	20,891

Such facts furnish a striking proof, how one trade, left perfectly free, may assist and develope another branch of industry, which was not even in existence at the period when the impost was repealed. The removal of the duty on the import of pig lead, has thus assisted the paper trade to meet the effects of recent legislation, to which special reference is made in the Report on the Manufacture of Paper.

Further, the impolicy of restrictive measures in trade is shown in the effects of the action of the late Neapolitan Government, in imposing a duty on the export of sulphur, which has been nearly superseded in our chemical manufactures by sulphur ores. Many of these ores contain copper, but in so small a proportion, as not to pay for its extraction, except by the utilization of the sulphur; and we are now

witnessing one of the consequences of the above measures, in the working of poor cupreous sulphur ores on the Tyne.

These facts assist in proving the wisdom of the legislation of late years in giving the most perfect freedom to trade and commerce, from which we anticipate that this district will continue to reap additional benefit, whilst we trust that the increasing employment for our deserving and hard-working population, will be accompanied with greater comfort in their homes, and the healthy intellectual, moral, and religious improvement of all who are earning their daily bread by the labour of their hands.

In conclusion, we may be permitted to refer to the recent Act of Parliament for the inspection of alkali works, and to congratulate the manufacturers on the appointment of Dr. Smith, whom we believe to be, in every way, qualified to discharge the difficult and delicate duties of this office. We also believe, that in the great majority of the alkali works of this district, he will find the most efficient apparatus for the perfect condensation of all the acid vapours, and a most earnest wish, on the part of the manufacturers, to adopt any really practical improvement in the management of their works.

NOTE.—Sailing vessels—Newcastle average, 238 tons; North Shields, 275 tons; South Shields, 429 tons; Sunderland, 245 tons; Hartlepool, 290 tons; West Hartlepool, 173 tons; Middlesbro', 144 tons; Stockton, 225 tons. Tyne ports average, 296 tons; Wear, 245 tons; Tees, 220 tons. Aggregate average, 256 tons.

Printing Court Buildings, Newcastle-upon-Tyne,
11th August, 1864.

PUBLISHER'S PREFACE TO THE FIRST EDITION.

In the year 1855, the late Mr. Thos. J. Taylor and Dr. Richardson commenced to collect information connected with the introduction, into this district, of the various manufactures for which it is now so celebrated; the numerous improvements which had their origin here; and the development of the different mining and manufacturing industries within a recent period.

The lamented death of the former gentleman suspended the execution of the work for a time; but the visit of the British Association was deemed a fitting occasion to complete the task, and the willing coöperation of various gentlemen has resulted in the publication of the several reports which constitute the present volume.

This locality is peculiarly rich in these records, inasmuch as it is the birthplace of the Locomotive and the Railway system, which has received such a development here that there are now three linear miles of railway for every square mile of surface; it has witnessed the introduction of the Glass, Alum, and Soda trades, which were all first commenced in this district; it was here that Stephenson invented his Safety-lamp, and Pattinson the Desilverizing of Lead, whilst Buddle perfected the Furnace Ventilation of Mines; and, lastly, the country owes its most valuable arm of defence to the ingenuity of Sir W. G. Armstrong, of Elswick.

The extraordinary advantages of this district are only now being recognised. There are six harbours, within 54 miles of coast, for its Shipping; every variety of Fuel,

Steam, Gas, Coking, and Household Coal in the same basin; Magnesian and Mountain Limestones, with cheap imports of Chalk, furnishing supplies of lime for its chemical and metallurgical operations; immense deposits of Fire Clay, providing for all the demands of its furnaces; and inexhaustible beds of argillaceous and calcareous Iron Ores, with Hematites of the best description; form the durable basis of its extending trade and commerce.

The recent discovery of the bed of Rock Salt at Middlesbro' will, ere long, add Salt to its list of available mineral riches.

The enterprise of its inhabitants is not, however, confined to the mere raising and export of some of its mineral treasures, as 20,000 tons of lead, 550,000 tons of iron, 170,000 tons of chemicals, and 300,000 tons of clay wares, in addition to its glass and paper, are annually manufactured on the banks of its rivers.

The district can also point to the celebrated engineering and shipbuilding factories of Stephenson, Hawthorn, Armstrong, Palmer, Bell, and many others, whose locomotives and engines, hydraulic machinery, guns, and ships, have acquired an European reputation.

In conclusion, the following Tables of the annual value of the Mining and Manufactured Products, and of the Shipping with cargoes, outwards and inwards, will give some idea of the Industrial Resources of the District.

MINING AND MANUFACTURED PRODUCTS.

Coals	£6,650,471
Metallurgical Products	3,707,941
Chemical Manufactures	1,583,220
Paper	300,000
Leather	135,659
Glass and Clay Wares	1,066,650
Iron Shipbuilding	1,643,328
Engines and Machinery	1,928,600

SHIPPING.

River District.	Port.	Inwards. British.	Inwards. Foreign.	Outwards. British.	Outwards. Foreign.
COASTING TRADE.					
Tyne...	Newcastle-on-Tyne ...	295,217	29,910	1,607,420	175
	North and South Shields	63,700	22,781	93,941	......
Wear..	Sunderland	122,511	......	1,596,126	......
Tees...	Hartlepool	25,067	364	797,130	......
	Middlesbro'	45,790	509	181,916	201
	Stockton	28,459	......	25,393	70
Total Tonnage of the District of the Three Rivers		580,744	53,564	4,301,926	446
FOREIGN TRADE.					
Tyne...	Newcastle-on-Tyne ...	160,455	100,132	840,273	663,357
	North and South Shields	25,629	28,299	129,234	19,406
Wear..	Sunderland	29,914	52,859	495,306	257,551
Tees...	Hartlepool	111,878	74,029	267,639	187,118
	Middlesbro'	4,454	6,449	104,146	56,408
	Stockton	7,791	14,082	1,424	2,567
Total Tonnage of the District of the Three Rivers		340,116	275,850	1,838,022	1,186,402
Total Tonnage of the Coasting and Foreign Trades		Inwards. 1,250,274		Outwards. 7,326,796	

The Total Tonnage Outwards of the United Kingdom for 1862, was as follows:—

Foreign Trade	13,444,339
Coasting do.	17,494,482
	30,938,821

Hence, nearly one quarter of the outward trade of the United Kingdom was carried on from these North-Eastern Ports.

In the pages which follow, the reader will find detailed the entire Industrial Progress which has at length resulted in the above figures; and to these the Publisher respectfully refers.

It may be proper to add, that it was originally proposed that this volume should have formed one of the series of the Transactions of the North of England Institute of Mining Engineers. By the advice, however, of the President of that Institution, the eminent mining engineer, Nicholas Wood, Esq., the work has assumed its present shape.

Printing Court Buildings, Newcastle-on-Tyne,
10th February, 1864.

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THE INAUGURAL ADDRESS.

BY

SIR WILLIAM G. ARMSTRONG, C.B., LL.D., F.R.S., &c.

GENTLEMEN OF THE BRITISH ASSOCIATION,

I esteem it the greatest honour of my life, that I am called upon to assume the office of your President. In that capacity, and as representing your body, I may be allowed to advert to the gratifying reception which the British Association met with on their former visit to this region of mining and manufacturing industry, and, as a member of the community which you have again honoured with a visit, I undertake to convey to you the assurance of a renewed and hearty welcome. A quarter of a century has elapsed since the Association assembled in this town, and in no former period of equal duration has so great a progress been made in physical knowledge. In mechanical science, and especially in those branches of it which are concerned in the application of steam power to effect interchange between distant communities, the progress made since 1838 has no parallel in history. The Railway system was then in its infancy, and the great problem of Transatlantic steam navigation had only received its complete solution in the preceding year. Since that time railways have extended to every continent, and steamships have covered the ocean. These reflections claim our attention

on this occasion, because the locality in which we hold our present meeting is the birthplace of railways, and because the coal-mines of this district have contributed more largely than any others to supply the motive power by which steam communication by land and water has been established on so gigantic a scale.

The history of railways shows what grand results may have their origin in small beginnings. When coal was first conveyed in this neighbourhood from the pit to the shipping place on the Tyne, the pack-horse, carrying a burden of 3 cwts., was the only mode of transport employed. As soon as roads suitable for wheeled carriages were formed, carts were introduced, and this first step in mechanical appliance to facilitate transport had the effect of increasing the load which the horse was enabled to convey from 3 cwts. to 17 cwts. The next improvement consisted in laying wooden bars or rails for the wheels of the carts to run upon, and this was followed by the substitution of the four-wheeled wagon for the two-wheeled cart. By this further application of mechanical principles, the original horse-load of 3 cwts. was augmented to 42 cwts. These were important results, and they were not obtained without the shipwreck of the fortunes of at least one adventurous man whose ideas were in advance of the times in which he lived. We read, in a record published in the year 1649, that "one Master Beaumont, a gentleman of great ingenuity and rare parts, adventured into the mines of Northumberland with his £30,000, and brought with him many rare engines not then known in that shire, and wagons with one horse to carry down coal from the pits to the river, but within a few years he consumed all his money, and rode home upon his light horse." The next step in the progress of railways was the attachment of slips of iron to the wooden rails.

Then came the iron tramway, consisting of cast-iron bars of an angular section : in this arrangement the upright flange of the bar acted as a guide to keep the wheel on the track. The next advance was an important one, and consisted in transferring the guiding flange from the rail to the wheel: this improvement enabled cast-iron edge rails to be used. Finally, in 1820, after the lapse of about 200 years from the first employment of wooden bars, wrought iron rails, rolled in long lengths, and of suitable section, were made in this neighbourhood, and eventually superseded all other forms of railway. Thus, the railway system, like all large inventions, has risen to its present importance by a series of steps; and so gradual has been its progress, that Europe finds itself committed to a gauge fortuitously determined by the distance between the wheels of the carts, for which wooden rails were originally laid down.

Last of all came the locomotive engine, that crowning achievement of mechanical science, which enables us to convey a load of 200 tons at a cost of fuel scarcely exceeding that of the corn and hay which the original pack-horse consumed in conveying its load of 3 cwts. an equal distance.

It was chiefly in this locality that the railway system was thus reared from earliest infancy to full maturity, and amongst the many names associated with its growth, that of George Stephenson stands preëminent.

In thus glancing at the history of railways, we may observe how promptly the inventive faculty of man supplies the device which the circumstances of the moment require. No sooner is a road formed fit for wheeled carriages to pass along, than the cart takes the place of the pack-saddle—no sooner is the wooden railway provided than the wagon is substituted for the cart—and no sooner

is an iron railway formed, capable of carrying heavy loads, than the locomotive engine is found ready to commence its career. As in the vegetable kingdom fit conditions of soil and climate quickly cause the appearance of suitable plants, so in the intellectual world fitness of time and circumstance promptly calls forth appropriate devices. The seeds of invention exist, as it were, in the air, ready to germinate whenever suitable conditions arise, and no legislative interference is needed to ensure their growth in proper season.

The coal-fields of this district, so intimately connected with the railway system, both in its origin and maintenance, will doubtless receive much attention from the Association at their present meeting.

To persons who contend that all geological phenomena may be attributed to causes identical in nature and degree with those now in operation, the formation of coal must present peculiar difficulty. The rankness of vegetation which must have existed in the carboniferous era, and the uniformity of climate which appears to have prevailed almost from the Poles to the Equator, would seem to imply a higher temperature of the earth's crust, and an atmosphere more laden with humidity and carbonic acid than exist in our day. But whatever may have been the geological conditions affecting the origin of coal, we may regard the deposits of that mineral as vast magazines of power, stored up at periods immeasurably distant, for our use.

The principle of conservation of force, and the relationship now established between heat and motion, enable us to trace back the effects which we now derive from coal to equivalent agencies exercised at the periods of its formation. The philosophical mind of George Stephenson, unaided by theoretical knowledge, rightly saw that coal was the

embodiment of power originally derived from the sun. That small pencil of solar radiation which is arrested by our planet, and which constitutes less than the 2000-millionth part of the total energy sent forth from the sun, must be regarded as the power which enabled the plants of the carboniferous period to wrest the carbon they required from the oxygen with which it was combined, and eventually to deposit it as the solid material of coal. In our day, the reünion of that carbon with oxygen restores the energy expended in the former process, and thus we are enabled to utilize the power originally derived from the luminous centre of our planetary system.

But the agency of the sun in originating coal does not stop at this point. In every period of geological history the waters of the ocean have been lifted by the action of the sun and precipitated in rain upon the earth. This has given rise to all those sedimentary actions by which mineral substances have been collected at particular localities, and there deposited in a stratified form with a protecting cover to preserve them for future use. The phase of the earth's existence suitable for the extensive formation of coal appears to have passed away for ever; but the quantity of that invaluable mineral which has been stored up throughout the globe for our benefit is sufficient (if used discreetly) to serve the purposes of the human race for many thousands of years. In fact, the entire quantity of coal may be considered as practically inexhaustible. Turning, however, to our own particular country, and contemplating the rate at which we are expending those seams of coal which yield the best quality of fuel, and can be worked at the least expense, we shall find much cause for anxiety. The greatness of England much depends upon the superiority of her coal in cheapness and quality over that of other

nations; but we have already drawn from our choicest mines a far larger quantity of coal than has been raised in all other parts of the world put together, and the time is not remote when we shall have to encounter the disadvantages of increased cost of working and diminished value of produce.

Estimates have been made at various periods of the time which would be required to produce complete exhaustion of all the accessible coal in the British Islands. These estimates are extremely discordant; but the discrepancies arise, not from any important disagreement as to the available quantity of coal, but from the enormous difference in the rate of consumption at the various dates when the estimates were made, and also from the different views which have been entertained as to the probable increase of consumption in future years. The quantity of coal yearly worked from British mines has been almost trebled during the last twenty years, and has probably increased tenfold since the commencement of the present century; but as this increase has taken place pending the introduction of steam navigation and railway transit, and under exceptional conditions of manufacturing development, it would be too much to assume that it will continue to advance with equal rapidity. The statistics collected by Mr. Hunt, of the Mining Records Office, show that at the end of 1861 the quantity of coal raised in the United Kingdom had reached the enormous total of 86,000,000 tons, and that the average annual increase of the eight preceding years amounted to 2,750,000 tons. Let us inquire, then, what will be the duration of our coal-fields if this more moderate rate of increase be maintained.

By combining the known thickness of the various workable seams of coal, and computing the area of the surface under which they lie, it is easy to arrive at an

estimate of the total quantity comprised in our coal-bearing strata. Assuming 4000 feet as the greatest depth at which it will ever be possible to carry on mining operations, and rejecting all seams of less than 2 feet in thickness, the entire quantity of available coal existing in these Islands has been calculated to amount to about 80,000 millions of tons, which, at the present rate of consumption, would be exhausted in 930 years, but with a continued yearly increase of 2,750,000 tons, would only last 212 years. It is clear that long before complete exhaustion takes place, England will have ceased to be a coal-producing country on an extensive scale. Other nations, and especially the United States of America, which possess coal-fields 37 times more extensive than ours, will then be working more accessible beds at a smaller cost, and will be able to displace the English coal from every market. The question is, not how long our coal will endure before absolute exhaustion is effected, but how long will those particular coal-seams last which yield coal of a quality and at a price to enable this country to maintain her present supremacy in manufacturing industry. So far as this particular district is concerned, it is generally admitted that 200 years will be sufficient to exhaust the principal seams even at the present rate of working. If the production should continue to increase as it is now doing, the duration of those seams will not reach half that period. How the case may stand in other coal-mining districts I have not the means of ascertaining; but as the best and most accessible coal will always be worked in preference to any other, I fear the same rapid exhaustion of our most valuable seams is everywhere taking place. Were we reaping the full advantage of all the coal we burnt, no objection could be made to the largeness of the quantity, but we are using it wastefully and extravagantly in all its applications. It is probable that

fully one-fourth of the entire quantity of coal raised from our mines is used in the production of heat for motive power; but, much as we are in the habit of admiring the powers of the steam-engine, our present knowledge of the mechanical energy of heat shows that we realize in that engine only a small part of the thermic effect of the fuel. That a pound of coal should, in our best engines, produce an effect equal to raising a weight of 1,000,000 pounds a foot high, is a result which bears the character of the marvellous, and seems to defy all further improvement. Yet the investigations of recent years have demonstrated the fact that the mechanical energy resident in a pound of coal, and liberated by its combustion, is capable of raising to the same height 10 times that weight. But although the power of our most economical steam-engines has reached, or perhaps somewhat exceeded, the limit of 1,000,000 pounds raised a foot high per lb. of coal, yet if we take the average effect obtained from steam-engines of the various constructions now in use, we shall not be justified in assuming it at more than one-third of that amount. It follows, therefore, that the average quantity of coal which we expend in realizing a given effect by means of the steam-engine is about 30 times greater than would be requisite with an absolutely perfect heat-engine.

The causes which render the application of heat so uneconomic in the steam-engine have been brought to light by the discovery of the dynamical theory of heat; and it now remains for mechanicians, guided by the light they have thus received, to devise improved practical methods of converting the heat of combustion into available power.

Engines in which the motive power is excited by the communication of heat to fluids already existing in the aëriform condition, as in those of Stirling, Ericson, and Siemens, promise to afford results greatly superior to those

obtained from the steam-engine. They are all based upon the principle of employing fuel to generate sensible heat, to the exclusion of latent heat, which is only another name for heat which has taken the form of unprofitable motion amongst the particles of the fluid to which it is applied. They also embrace what is called the regenerative principle—a term which has, with reason, been objected to, as implying a restoration of expended heat. The so-called "regenerator" is a contrivance for arresting unutilized heat rejected by the engine, and causing it to operate in aid and consequent reduction of fuel.

It is a common observation that before coal is exhausted some other motive agent will be discovered to take its place, and electricity is generally cited as the coming power. Electricity, like heat, may be converted into motion, and both theory and practice have demonstrated that its mechanical application does not involve so much waste of power as takes place in a steam-engine; but whether we use heat or electricity as a motive power, we must equally depend upon chemical affinity as the source of supply. The act of uniting to form a chemical product liberates an energy which assumes the form of heat or electricity, from either of which states it is convertible into mechanical effect. In contemplating, therefore, the application of electricity as a motive power, we must bear in mind that we shall still require to effect chemical combinations, and in so doing to consume materials. But where are we to find materials so economical for this purpose as the coal we derive from the earth and the oxygen we obtain from the air? The latter costs absolutely nothing; and every pound of coal, which in the act of combustion enters into chemical combination, renders more than two and a half pounds of oxygen available for power. We cannot look to water as a

practicable source of oxygen, for there it exists in the combined state, requiring expenditure of chemical energy for its separation from hydrogen. It is in the atmosphere alone that it can be found in that free state in which we require it, and there does not appear to me to be the remotest chance, in an economic point of view, of being able to dispense with the oxygen of the air as a source either of thermodynamic or electrodynamic effect. But to use this oxygen we must consume some oxidizable substance, and coal is the cheapest we can procure.

There is another source of motive power to which I am induced to refer, as exhibiting a further instance in which solar influence affords the means of obtaining mechanical effects from inanimate agents. I allude to the power of water descending from heights to which it has been lifted by the evaporative action of the sun. To illustrate the great advantage of collecting water for power in elevated situations, I may refer to the waterworks of Greenock, where the collecting-reservoirs are situated at an elevation of 512 feet above the river Clyde. The daily yield of these reservoirs is said to be nearly 100,000 tons of water, which is derived from the rainfall on an area of 5000 acres. The power obtainable from this quantity and head of water is equal to that of a steam-engine of about 2000-horse power, and the whole effect might be realized on the margin of the river by bringing down the water in a pipe of sufficient capacity, and causing it to act as a column on suitable machinery at the foot of the descent. But the hydraulic capabilities of the Greenock reservoirs sink into insignificance when compared with those of other localities, where the naturally collected waters of large areas of surface descend, from great elevations, in rapid rivers or vertical falls. Alpine regions abound in falls which, with the aid

of artificial works to impound the surplus water and equalize the supply, would yield thousands of horse power; and there is at least one great river in the world which, in a single plunge, developes sufficient power to carry on all the manufacturing operations of mankind if concentrated in its neighbourhood. Industrial populations have scarcely yet extended to those regions which afford this profusion of motive power, but we may anticipate the time when these natural falls will be brought into useful operation. In that day the heat of the sun, by raising the water to heights from which to flow in these great rapids and cascades, will become the means of economizing the precious stores of motive power, which the solar energy differently directed has accumulated at a remote period of geological history, and which, when once expended, may probably never be replaced.

I have hitherto spoken of coal only as a source of mechanical power, but it is also extensively used for the kindred purpose of relaxing those cohesive forces which resist our efforts to give new forms and conditions to solid substances. In these applications, which are generally of a metallurgical nature, the same wasteful expenditure of fuel is everywhere observable. In an ordinary furnace employed to fuse or soften any solid substance, it is the excess of the heat of combustion over that of the body heated which alone is rendered available for the purpose intended. The rest of the heat, which in many instances constitutes by far the greater proportion of the whole, is allowed to escape uselessly into the chimney. The combustion also in common furnaces is so imperfect, that clouds of powdered carbon, in the form of smoke, envelope our manufacturing towns, and gases, which ought to be completely oxygenized in the fire, pass into the air with two-thirds of their heating power undeveloped.

Some remedy for this state of things, we may hope, is at hand, in the gas regenerative furnaces recently introduced by Mr. Siemens. In these furnaces the rejected heat is arrested by a so-called " regenerator," as in Stirling's air-engine, and is communicated to the new fuel before it enters the furnace. The fuel, however, is not solid coal, but gas previously evolved from coal. A stream of this gas raised to a high temperature by the rejected heat of combustion is admitted into the furnace, and there meets a stream of atmospheric air also raised to a high temperature by the same agency. In the combination which then ensues, the heat evolved by the combustion is superadded to the heat previously acquired by the gases. Thus, in addition to the advantage of economy, a greater intensity of heat is attained than by the combustion of unheated fuel. In fact, as the heat evolved in the furnace, or so much of it as is not communicated to the bodies exposed to its action, continually returns to augment the effect of the new fuel, there appears to be no limit to the temperature attainable, except the powers of resistance in the materials of which the furnace is composed.

With regard to smoke, which is at once a waste and a nuisance, having myself taken part with Dr. Richardson and Mr. Longridge in a series of experiments made in this neighbourhood, in the years 1857–58, for the purpose of testing the practicability of preventing smoke in the combustion of bituminous coal in steam-engine boilers, I can state with perfect confidence that, so far as the raising of steam is concerned, the production of smoke is unnecessary and inexcusable. The experiments to which I refer proved beyond a doubt, that by an easy method of firing, combined with a due admission of air and a proper arrangement of fire-grate, not involving any complexity, the emission of smoke might be perfectly avoided, and that the prevention

of the smoke increased the economic value of the fuel and the evaporative power of the boiler. As a rule, there is more smoke evolved from the fires of steam engines than from any others, and it is in these fires that it may be most easily prevented. But in the furnaces used for most manufacturing operations the prevention of smoke is much more difficult, and will probably not be effected until a radical change is made in the system of applying fuel for such operations.

Not less wasteful and extravagant is our mode of employing coal for domestic purposes. It is computed that the consumption of coal in dwelling-houses amounts in this country to a ton per head per annum of the entire population; so that upwards of twenty-nine millions of tons are annually expended in Great Britain alone for domestic use. If any one will consider that one pound of coal applied to a well-constructed steam-engine boiler, evaporates 10 lbs. or one gallon of water, and if he will compare this effect with the insignificant quantity of water which can be boiled off in steam by a pound of coal consumed in an ordinary kitchen fire, he will be able to appreciate the enormous waste which takes place by the common method of burning coal for culinary purposes. The simplest arrangements to confine the heat and concentrate it upon the operation to be performed would suffice to obviate this reprehensible waste. So, also, in warming houses we consume in our open fires about five times as much coal as will produce the same heating effect when burnt in a close and properly constructed stove. Without sacrificing the luxury of a visible fire, it would be easy, by attending to the principles of radiation and convection, to render available the greater part of the heat which is now so improvidently discharged into the

chimney. These are homely considerations—too much so, perhaps, for an assembly like this—but I trust that an abuse involving a useless expenditure exceeding in amount our income-tax, and capable of being rectified by attention to scientific principles, may not be deemed unworthy of the notice of some of those whom I have the honour of addressing.

The introduction of the Davy-lamp was a great event in the history of coal-mining, not as effecting any great diminution of those disastrous accidents which still devastate every colliery district, but as a means of enabling mines to be worked which, from their greater explosive tendencies, would otherwise have been deemed inaccessible. Thus, while the Davy-lamp has been of great benefit both to the public and the proprietors of coal, it has been the means of leading the miners into more perilous workings, and the frequency of accident by explosion has, in consequence, not been diminished to the extent which was originally expected. The Davy-lamp is a beautiful application of a scientific principle to effect a practical purpose, and with fair treatment its efficiency is indisputable; but where Davy-lamps are entrusted to hundreds of men, and amongst them to many careless and reckless persons, it is impossible to guard entirely against gross negligence and its disastrous consequences. In coal-mines where the most perfect system of ventilation prevails and where proper regulations are, as far as practical, enforced in regard to the use of Davy-lamps, deplorable accidents do occasionally occur, and it is impossible at present to point out what additional precautions would secure immunity from such calamities. The only gleam of amelioration is in the fact that the loss of life, in relation to the quantity of coal worked, is on the decrease, from

which we may infer that it is also on the decrease taken as a per centage on the number of miners employed.

The increase of the earth's temperature as we descend below the surface, is a subject which has been discussed at previous meetings of the British Association. It possesses great scientific interest as affecting the computed thickness of the crust which covers the molten mass, assumed to constitute the interior portions of the earth, and it is also of great practical importance as determining the depth at which it would be possible to pursue the working of coal and other minerals. The deepest coal mine in this district is the Monkwearmouth Colliery, which reaches a depth of 1800 feet below the surface of the ground, and nearly as much below the level of the sea. The observed temperature of the strata at this depth agrees pretty closely with what has been ascertained in other localities, and shows that the increase takes place at the rate of 1° Fahr. to about 60 feet of depth. Assuming the temperature of subterranean fusion to be 3000°, and that the increase of heat at greater depths continues uniform (which, however, is by no means certain), the thickness of the film which separates us from the fiery ocean beneath will be about thirty-four miles—a thickness which may be fairly represented by the skin of a peach taken in relation to the body of the fruit which it covers. The depth of 4000 feet, which has been assumed as the limit at which coal could be worked, would probably be attended by an increase of heat exceeding the powers of human endurance. In the Monkwearmouth Colliery, which is less than half that depth, the temperature of the air in the workings is about 84° Fahr., which is considered to be nearly as high as is consistent with the great bodily exertion necessary in the operation of mining. The computations therefore, of the duration of coal would probably require a

considerable reduction, in consequence of too great a depth being assumed as practicable.

At the last meeting of the British Association in this town, the importance of establishing an office for mining records was brought under the notice of the Council by Mr. Sopwith, and measures were taken which resulted in the formation of the present Mining Records Office. The British Association may congratulate itself upon having thus been instrumental in establishing an office in which plans of abandoned mines are preserved for the information of those who, at a future period, may be disposed to incur the expense of bringing those mines again into operation. But more than this is required. Many of the inferior seams of coal can be worked only in conjunction with those of superior quality, and they will be entirely lost if neglected until the choicer beds be exhausted. Although coal is private property, its duration is a national question, and Government interference would be justified to enforce such modes of working as the national interests demand. But to enable Government to exercise any supervision and control, a complete mining survey of all our coal-fields should be made, and full plans, sections, and reports lodged at the Mining Records Office for the information of the Legislature and of the public in general.

Before dismissing the subject of coal, it may be proper to notice the recent discovery by Berthelot of a new form of carburetted hydrogen possessing twice the illuminating power of ordinary coal-gas. Berthelot succeeded in procuring this gas by passing hydrogen between the carbon electrodes of a powerful battery. Dr. Odling has since shown that the same gas may be produced by mixing carbonic oxide with an equal volume of light carburetted hydrogen, and exposing the mixture in a porcelain tube to

an intense heat. Still more recently, Mr. Siemens has detected the same gas in the highly heated regenerators of his furnaces, and there is now every reason to believe that the new gas will become practically available for illuminating purposes. Thus it is that discoveries which in the first instance, interest the philosopher only, almost invariably initiate a rapid series of steps leading to results of great practical importance to mankind.

In the course of the preceding observations I have had occasion to speak of the sun as the great source of motive power on our earth, and I must not omit to refer to recent discoveries conneeted with that most glorious body. Of all the results which science has produced within the last few years, none has been more unexpected than that by which we are enabled to test the materials of which the sun is made, and prove their identity, in part at least, with those of our planet. The spectrum experiments of Bunsen and Kirchhoff have not only shown all this, but they have also corroborated previous conjectures as to the luminous envelope of the sun. I have still to advert to Mr. Nasmyth's remarkable discovery, that the bright surface of the sun is composed of an aggregation of apparently solid forms, shaped like willow-leaves, or some well known forms of Diatomaceæ, and interlacing one another in every direction. The forms are so regular in size and shape, as to have led to a suggestion from one of our profoundest philosophers of their being organisms, possibly even partaking of the nature of life, but at all events closely connected with the heating and vivifying influences of the sun. These mysterious objects, which, since Mr. Nasmyth discovered them, have been seen by other observers as well, are computed to be each not less than 1000 miles in length and about 100 miles in breadth. The enormous chasms in the sun's photosphere, to which we apply the diminutive

term "spots," exhibit the extremities of these leaf-like bodies pointing inwards, and fringing the sides of the cavern far down into the abyss. Sometimes they form a sort of rope or bridge across the chasm, and appear to adhere to one another by lateral attraction. I can imagine nothing more deserving of the scrutiny of observers than these extraordinary forms. The sympathy also which appears to exist between forces operating in the sun, and magnetic forces belonging to the earth, merits a continuance of that close attention which it has already received from the British Association, and of labours such as General Sabine has with so much ability and effect devoted to the elucidation of the subject. I may here notice that most remarkable phenomenon, which was seen by independent observers at two different places on the 1st September, 1859. A sudden outburst of light, far exceeding the brightness of the sun's surface, was seen to take place, and sweep like a drifting cloud over a portion of the solar face. This was attended with magnetic disturbances of unusual intensity, and with exhibitions of aurora of extraordinary brilliancy. The identical instant at which the effusion of light was observed was recorded by an abrupt and strongly marked deflection in the self-registering instruments at Kew. The phenomenon as seen was probably only part of what actually took place, for the magnetic storm in the midst of which it occurred commenced before and continued after the event. If conjecture be allowable in such a case, we may suppose that this remarkable event had some connection with the means by which the sun's heat is renovated. It is a reasonable supposition that the sun was at that time in the act of receiving a more than usual accession of new energy; and the theory which assigns the maintenance of its power to cosmical matter, plunging into it with that prodigious velocity

which gravitation would impress upon it as it approached to actual contact with the solar orb, would afford an explanation of this sudden exhibition of intensified light in harmony with the knowledge we have now attained, that arrested motion is represented by equivalent heat. Telescopic observations will probably add new facts to guide our judgment on this subject, and, taken in connection with observations on terrestrial magnetism, may enlarge and correct our views respecting the nature of heat, light, and electricity. Much as we have yet to learn respecting these agencies, we know sufficient to infer that they cannot be transmitted from the sun to the earth, except by communication from particle to particle of intervening matter. Not that I speak of particles in the sense of the atomist. Whatever our views may be of the nature of particles, we must conceive them as centres invested with surrounding forces. We have no evidence, either from our senses or otherwise, of these centres being occupied by solid cores of indivisible incompressible matter essentially distinct from force. Dr. Young has shown that even in so dense a body as water, these nuclei, if they exist at all, must be so small in relation to the intervening spaces, that a hundred men distributed at equal distances over the whole surface of England, would represent their relative magnitude and distance. What then must be these relative dimensions in highly rarefied matter? But why encumber our conceptions of material forces by this unnecessary imagining of a central molecule? If we retain the forces and reject the molecule, we shall still have every property we can recognize in matter by the use of our senses or by the aid of our reason. Viewed in this light, matter is not merely a thing subject to force, but is itself composed and constituted of force.

The dynamical theory of heat is probably the most

important discovery in the present century. We now know that each Fahrenheit degree of temperature in a pound of water is equivalent to a weight of 772 lbs. lifted 1 foot high, and that these amounts of heat and power are reciprocally convertible into one another. This theory of heat, with its numerical computation, is chiefly due to the labours of Mayer and Joule, though many other names, including those of Thomson and Rankine, are deservedly associated with its development. I speak of this discovery as one of the present age, because it has been established in our time; but if we search back for earlier conceptions of the identity of heat and motion, we shall find (as we always do in such cases) that similar ideas have been held before, though in a clouded and undemonstrated form. In the writings of Lord Bacon we find it stated that heat is to be regarded as motion and nothing else. In dilating upon this subject, that extraordinary man shows that he had grasped the true theory of heat, to the utmost extent that was compatible with the state of knowledge existing in his time. Even Aristotle seems to have entertained the idea, that motion was to be considered as the foundation not only of heat, but of all manifestations of matter; and, for aught we know, still earlier thinkers may have held similar views.

The science of gunnery, to which I shall make but slight allusion on this occasion, is intimately connected with the dynamical theory of heat. When gunpowder is exploded in a cannon, the immediate effect of the affinities by which the materials of the powder are caused to enter new combinations, is to liberate a force which first appears as heat, and then takes the form of mechanical power communicated in part to the shot and in part to the products of explosion which are also propelled from the gun. The mechanical force of the shot is reconverted into heat when the motion

is arrested by striking an object, and this heat is divided between the shot and the object struck, in the proportion of the work done or damage inflicted upon each. These considerations recently led me, in conjunction with my friend Captain Noble, to determine experimentally, by the heat elicited in the shot, the loss of effect due to its crushing when fired against iron plates. Joule's law, and the known velocity of the shot, enabled us to compute the number of dynamical units of heat representing the whole mechanical power in the projectile, and by ascertaining the number of units developed in it by impact, we arrived at the power which took effect upon the shot instead of the plate. These experiments showed an enormous absorption of power to be caused by the yielding nature of the materials of which projectiles are usually formed; but further experiments are required to complete the inquiry.

Whilst speaking of the subject of gunnery, I must pay a passing tribute of praise to that beautiful instrument, invented and perfected by Major Navez, of the Belgian Artillery, for determining, by means of electro-magnetism, the velocity of projectiles. This instrument has been of great value in recent investigations, and there are questions affecting projectiles which we can only hope to solve by its assistance. Experiments are still required to clear up several apparently anomalous effects in gunnery, and to determine the conditions most conducive to efficiency, both as regards attack and defence. It is gratifying to see our Government acting in accordance with the enlightened principles of the age, by carrying on scientific experiments to arrive at knowledge which, in the arts of war as well as in those of peace, is proverbially recognised as the true source of human power.

Professor Tyndall's recent discoveries respecting the

absorption and radiation of heat by vapours and permanent gases constitute important additions to our knowledge. The extreme delicacy of his experiments, and the remarkable distinctness of their results, render them beautiful examples of physical research. They are of great value as affording further illustrations of the vibratory actions in matter which constitute heat; but it is in connection with the science of meteorology that they chiefly command our attention. From these experiments we learn that the minute quantity of water suspended as invisible vapour in the atmosphere acts as a warm clothing to the earth. The efficacy of this vapour in arresting heat is, in comparison with that of air, perfectly astounding. Although the atmosphere contains, on an average, but one particle of aqueous vapour to 200 of air, yet that single particle absorbs 80 times as much heat as the collective 200 particles of air. Remove, says Professor Tyndall, for a single summer night, the aqueous vapour from the air which overspreads this country, and you would assuredly destroy every plant incapable of bearing extreme cold. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the grip of frost. Many meteorological phenomena receive a feasible explanation from these investigations, which are probably destined to throw further light upon the functions of our atmosphere.

Few sciences have more practical value than meteorology, and there are few of which we as yet know so little. Nothing would contribute more to the saving of life and property, and to augmenting the general wealth of the world, than the ability to foresee, with certainty, impending changes of the weather. At present our means of doing so are exceedingly imperfect; but, such as they are, they

have been employed with considerable effect by Admiral Fitzroy, in warning mariners of the probable approach of storms. We may hope that so good an object will be effected, with more unvarying success, when we attain a better knowledge of the causes by which wind and rain, heat and cold, are determined. The balloon explorations, conducted with so much intrepidity by Mr. Glaisher, under the auspices of the British Association, may, perhaps, in some degree, assist in enlightening us upon these important subjects. We have learnt from Mr. Glaisher's observations, that the decrease of temperature with elevation does not follow the law previously assumed of 1° in 300 feet, and that, in fact, it follows no definite law at all. Mr. Glaisher appears also to have ascertained the interesting fact, that rain is only precipitated when cloud exists in a double layer. Rain-drops, he has found, diminish in size with elevation, merging into wet mist, and ultimately into dry fog. Mr. Glaisher met with snow for a mile in thickness below rain, which is at variance with our preconceived ideas. He has also rendered good service by testing the efficiency of various instruments at heights which cannot be visited without personal danger.

The facility now given to the transmission of intelligence and the interchange of thought is one of the most remarkable features of the present age. Cheap and rapid postage to all parts of the world—paper and printing reduced to the lowest possible cost—electric telegraphs between nation and nation, town and town, and now even (thanks to the beautiful inventions of Professor Wheatstone) between house and house—all contribute to aid that commerce of ideas by which wealth and knowledge are augmented. But while so much facility is given to mental communication by new measures and new inventions, the fundamental art

of expressing thought by written symbols remains as imperfect now as it has been for centuries past. It seems strange that, while we actually possess a system of shorthand by which words can be recorded as rapidly as they can be spoken, we should persist in writing a slow and laborious longhand. It is intelligible that grown-up persons who have acquired the present conventional art of writing should be reluctant to incur the labour of mastering a better system; but there can be no reason why the rising generation should not be instructed in a method of writing more in accordance with the activity of mind which now prevails. Even without going so far as to adopt for ordinary use a complete system of stenography, which it is not easy to acquire, we might greatly abridge the time and labour of writing by the recognition of a few simple signs to express the syllables which are of most frequent occurrence in our language. Our words are in a great measure made up of such syllables as *com*, *con*, *tion*, *ing*, *able*, *ain*, *ent*, *est*, *ance*, *&c.* These we are now obliged to write out over and over again, as if time and labour expended in what may be termed visual speech were of no importance. Neither has our written character the advantage of distinctness to recommend it: it is only necessary to write such a word as "minimum" or "ammunition" to become aware of the want of sufficient difference between the letters we employ. I refrain from enlarging on this subject, because I conceive that it belongs to social more than to physical science, although the boundary which separates the two is sufficiently indistinct to permit of my alluding to it, in the hope of procuring for it the attention which its importance deserves.

Another subject of a social character which demands our consideration is the much-debated question of weights

and measures. Whatever difference of opinion there may be as to the comparative merits of decimal and duodecimal division, there can, at all events, be none as to the importance of assimilating the systems of measurement in different countries. Science suffers by the want of uniformity, because valuable observations made in one country are in a great measure lost to another from the labour required to convert a series of quantities into new denominations. International commerce is also impeded by the same cause, which is productive of constant inconvenience and frequent mistake. It is much to be regretted that two standards of measure so nearly alike as the English yard and the French metre should not be made absolutely identical. The metric system has already been adopted by other nations besides France, and is the only one which has any chance of becoming universal. We in England, therefore, have no alternative but to conform with France, if we desire general uniformity. The change might easily be introduced in scientific literature, and in that case it would probably extend itself by degrees amongst the commercial classes without much legislative pressure. Besides the advantage which would thus be gained in regard to uniformity, I am convinced that the adoption of the decimal division of the French scale would be attended with great convenience, both in science and commerce. I can speak from personal experience of the superiority of decimal measurement in all cases where accuracy is required in mechanical construction. In the Elswick Works, as well as in some other large establishments of the same description, the inch is adopted as the unit, and all fractional parts are expressed in decimals. No difficulty has been experienced in habituating the workmen to the use of this method, and it has greatly contributed to precision of workmanship. The inch, however, is

too small a unit, and it would be advantageous to substitute the metre if general concurrence could be obtained. As to our thermometric scale, it was originally founded in error ; it is also most inconvenient in division, and ought at once to be abandoned in favour of the Centigrade scale. The recognition of the metric system, and of the Centigrade scale, by the numerous men of science composing the British Association, would be a most important step towards effecting that universal adoption of the French standards in this country, which sooner or later will inevitably take place ; and the Association, in its collective capacity, might take the lead in this good work, by excluding in future all other standards from their published proceedings.

The recent discovery of the source of the Nile, by Captains Speke and Grant, has solved a problem in geography which has been a subject of speculation from the earliest ages. It is an honour to England that this interesting discovery has been made by two of her sons, and the British Association, which is accustomed to value every addition to knowledge for its own sake, whether or not it be attended with any immediate utility, will at once appreciate the importance of the discovery, and the courage and devotion by which it has been accomplished. The Royal Geographical Society, under the able presidency of Sir Roderick Murchison, was chiefly instrumental in procuring the organization of the expedition which has resulted in this great achievement, and the success of the Society's labours, in connection with this and other cases of African exploration, shows how much good may be effected by associations for the promotion of scientific objects.

The science of organic life has of late years been making great and rapid strides ; and it is gratifying to observe, that researches, both in zoology and botany, are characterised,

in the present day, by great accuracy and elaboration. Investigations, patiently conducted upon true inductive principles, cannot fail eventually to elicit the hidden laws which govern the animated world. Neither is there any lack of bold speculation contemporaneously with this pains-taking spirit of inquiry. The remarkable work of Mr. Darwin, promulgating the doctrine of natural selection, has produced a profound sensation. The novelty of this ingenious theory, the eminence of its author, and his masterly treatment of the subject, have, perhaps, combined to excite more enthusiasm in its favour than is consistent with that dispassionate spirit which it is so necessary to preserve in the pursuit of truth. Mr. Darwin's views have not passed unchallenged, and the arguments, both for and against, have been urged with great vigour by the supporters and opponents of the theory. Where good reasons can be shown on both sides of a question, the truth is generally to be found between the two extremes. In the present instance we may, without difficulty, suppose it to have been part of the great scheme of Creation, that natural selection should be permitted to determine variations amounting even to specific differences, where those differences were matters of degree; but when natural selection is adduced as a cause adequate to explain the production of a new organ not provided for in original Creation, the hypothesis must appear, to common apprehensions, to be pushed beyond the limits of reasonable conjecture. The Darwinian theory, when fully enunciated, founds the pedigree of living nature upon the most elementary form of vitalized matter. One step further would carry us back, without greater violence to probability, to inorganic rudiments; and then we should be called upon to recognize in ourselves, and in the exquisite elaborations of the animal and vegetable kingdoms, the

ultimate results of mere material forces left free to follow their own unguided tendencies. Surely our minds would in that case be more oppressed with a sense of the miraculous, than they now are in attributing the wondrous things around us to the creative hand of a great presiding Intelligence.

The evidences bearing upon the antiquity of man have been recently produced, in a collected and most logically-treated form, by Sir Charles Lyell. It seems no longer possible to doubt that the human race has existed on the earth, in a barbarian state, for a period far exceeding the limit of historical record; but, notwithstanding this great antiquity, the proofs still remain unaltered, that man is the latest as well as the noblest work of God.

I will not run the risk of wearying this assembly by extending my remarks to other branches of science. In conclusion, I will express a hope that when the time again comes round to receive the British Association in this town, its members will find the interval to have been as fruitful as the corresponding period on which we now look back. The tendency of progress is to quicken progress, because every acquisition in science is so much vantage ground for fresh attainment. We may expect, therefore, to increase our speed as we struggle forward; but however high we climb in the pursuit of knowledge we shall still see heights above us, and the more we extend our view, the more conscious we shall be of the immensity which lies beyond.

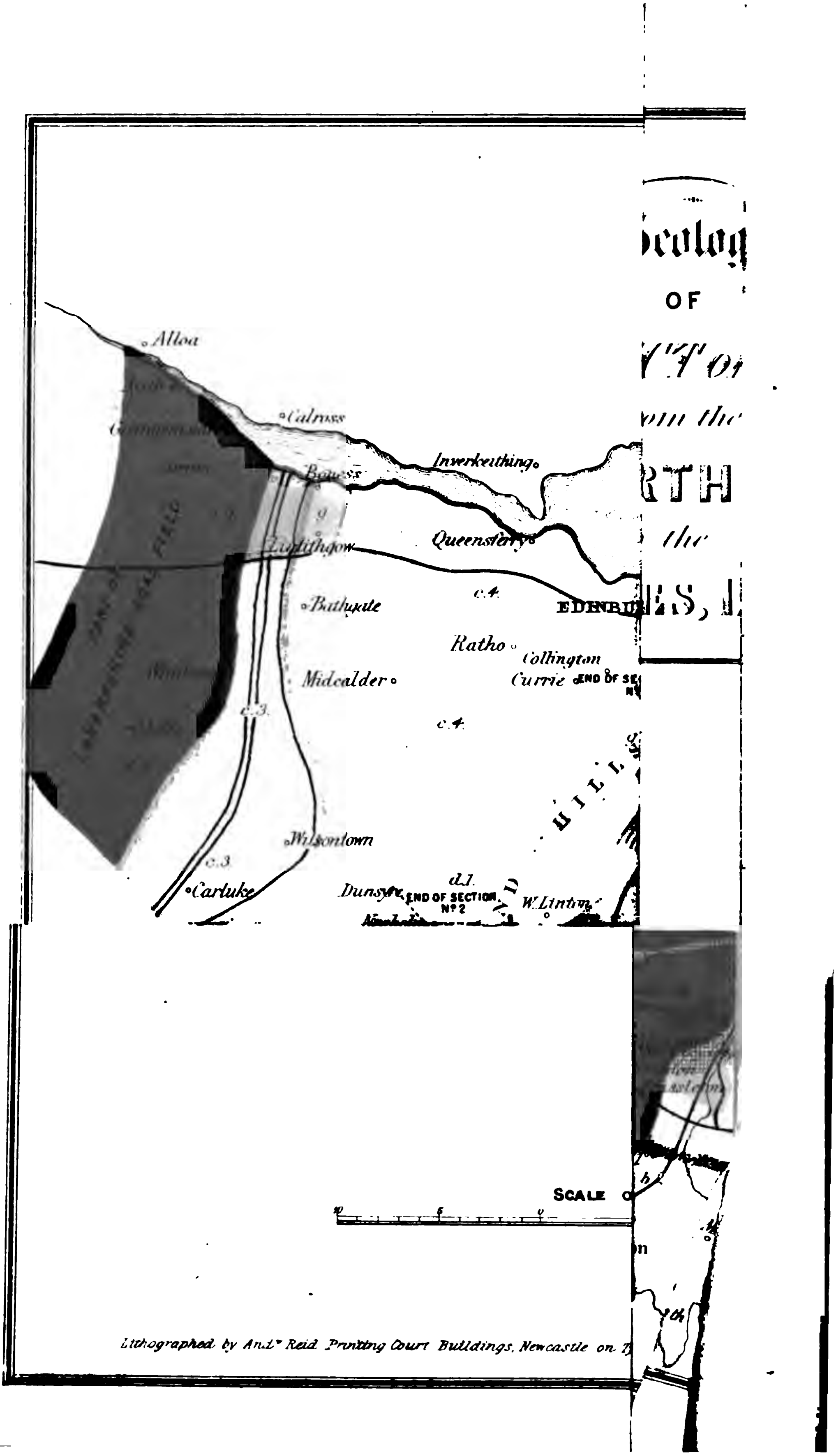
REPORT

ON

COAL, COKE, AND COAL MINING.

BY

NICHOLAS WOOD, J. TAYLOR, AND J. MARLEY.


OF
Alloa
Culross
Inverkeithing
Queensferry
Linlithgow
Bathgate
c.4
EDINBU
Ratho
Collington
Currie
Midcalder
c.3
c.4
Wilsontown
c.3
Carluke
d.1
Dunsyre
END OF SECTION
No 2
W. Linton
SCALE
Lithographed by And.w Reid Printing Court Buildings, Newcastle on T

COAL MINING, &c.

In the preparation of the following papers, those to whom they have been entrusted have availed themselves of the Plans and Sections of the Coal-field of Northumberland and Durham (four in number), which were prepared for the Coal Trade, under the supervision of Mr. William Oliver, colliery viewer, Stanhope, Weardale, and sent by the Coal Trade to the International Exhibition of 1862, and which are now exhibited on the walls of this room.

They would also draw attention to two most valuable papers by the late eminent mining engineer, Mr. Thomas John Taylor, one of which he read before the Archæological Society, in this town, in 1852, and the other before the Institute of Mechanical Engineers, at Birmingham, in 1859; to a paper read in this town, in 1858, by Mr. Nicholas Wood, to the Institute of Mechanical Engineers; and also to the several papers read to the North of England Institute of Mining Engineers by Messrs. Wood, Boyd, Dunn, Gibsone, Hall, and others, which have been published in their Transactions, and contain detailed particulars of the Geology and Deposits of the Northern Coal-fields; and to the papers by Messrs. Wood, Bewick, and Marley on the Cleveland Ironstone District.

For the purpose of illustrating and explaining the subjects included in this Section, the following divisions have been adopted, viz.:—

1. Geological Description of the Northern Coal-field, including the Dykes intersecting it, and other prominent features.
2. On the Economic and Industrial Uses of the various Beds of Coal in the North of England Coal-field, and their local distribution.
3. The Early History of the Coal and Coke Trade, more particularly referring to this District.

4. A brief Statement of the Development of the Coal and Coke Trade up to the present time, including some important Statistics.
5. An Account of New Discoveries and their Application, explaining the manner in which they affect the Coal and Coke Trade.
6. On the Sinking of Pits and the Drainage of Mines.
7. On the Mode of Working Mines.
8. On the Ventilation and Lighting of Mines.
9. On the Underground Conveyance of Coal.
10. On the Effects produced by the Introduction of Railways, Locomotives, Screw Steamers, and Inland Competition on the Commercial Character and Condition of the Northern Coal Trade.
11. On the Duration of the Coal-field.

A reference to the Coal Trade Map, and to the map and sections accompanying this paper, will show that the principal rivers of this district are geologically situated as follows:—

TYNE.

The south branch of this river rises in the eastern flank of Cross Fell, in the series of rocks of the Carboniferous formation, above the Great Whin Sill, which are denominated "Yoredale" rocks by Professor Phillips. It flows northerly through the whole series of the Yoredale rocks, till these are thrown down to the north by the great Ninety-Fathom or Stublick Dyke. Then it takes an easterly course, running along the depression caused by this dyke, through the Yoredale series, receiving the North Tyne between Haydon Bridge and Hexham. Below the latter place it passes through the Millstone Grit series, till, on reaching Stocksfield, it cuts through the lower parts of the Coal-measures, over which it flows for 20 miles, till it reaches the sea at Tynemouth, near the junction of the Coal-measures and the Permain rocks. The North Tyne rises in the Scar-limestone series of the Carboniferous formation, cuts through the coal beds of the Plashetts district—crosses the Great Whin Sill below Wark, and then traverses a portion of the Yoredale rocks, till it joins the South Tyne. It has for the most part a south-easterly course.

WEAR.

The Wear rises, and is enclosed, in a narrow valley, bounded by the valleys of the Tyne and Tees. It flows easterly over the Carbonife-

rous rocks of the Yoredale series, cutting them deeply, and forming a section from the Great Whin Sill to the Millstone Grit series, which it traverses; and on entering the Coal-measures it is deflected to the north by the elevated escarpment of the Magnesian-limestone. It runs through the denuded valley of the Coal-measures, nearly parallel with this escarpment, till it approaches the valley of the Tyne, when it suddenly deflects to the east, and passes through a denudation of the Magnesian-limestone to the sea at Sunderland.

TEES.

The Tees rises high up the south-eastern flank of Cross Fell, in the Yoredale series of the Carboniferous-limestone. It flows nearly due east through a deep valley, cut into the Cross Fell range. At the foot of this valley it formed, in more ancient times, a lake, the bed of which, forming a broadish river channel, exists to the present day, and is called the "Wheel." At the lower extremity of the "Wheel" the river precipitates itself in a fine waterfall (Cauldron Snout) over the Great Whin Sill, which attains nearly its maximum thickness in this locality. It then, joined by a small tributary, runs through a deepened valley, which, in all probability, it has cut for itself through the Whin Sill for several miles, when again, at the High Force, it is precipitated over the same bed, which has been thrown down by a fault. After extricating itself from its Whin Sill barrier, it flows, with a somewhat more easterly course, through a more open valley, and intersects the upper beds of the Yoredale rocks, the Millstone Grit series, and cuts through the Magnesian-limestone near Pierce Bridge, and has the remainder of its course, which has now become sluggish, through the sandstones of the New-red-sandstone formation. Near its mouth commences the Liassic series of rocks, containing among its members the valuable beds of ironstone of the Cleveland district.

A very good general view of the Northern Coal-field, with its various seams of coal and the depths of the different pits, will be obtained by an examination of the Coal Trade plans and sections, viz.:—

1. *Section from North to South*, from the river Coquet, at the northern extremity of the lower beds of the coal-field, to South Wingate, the southernmost colliery in the south of the county of Durham, where it seems to end by the passage upwards of the two workable seams into the unconformable Magnesian-limestone. (See section 4.)

2. *Section from East to West*, from Tynemouth, at the mouth of the Tyne, to Heddon-on-the-Wall, on the north of the Tyne.

3. ***Section from East to West,*** from Monkwearmouth, near the mouth of the Wear, to Hownes Gill. (See section 3.)

In order to identify the various seams of each district, a synopsis of the nomenclature is here given, corrected down to the present date, from the original paper read before the Natural History Society of Newcastle-on-Tyne, in 1830, by the late eminent mining engineer, John Buddle, Esq.

OF TI

.A R.

COK

BRANC

Thickness of Seam.

NAME OF

ft. in.

2·4

3·5

6·6

1·6

4·1

4·6

3·0 Harve

Broc

OF THE TY

A R.

Thickness of Seam.	COKING AND GA[S] DISTRICT.		
	BRANCEPETH & CR[O] DISTRICT.		
	NAME OF SEAM.	Distance between Seams.	Depth from Surface.
ft. in.		Fms.	Fms.
2·4			
3·5			
6·6			
1·6			
4·1			
4·6			
8·0	Harvey.........		19.
	Brockwell......		

No. 1.—GEOLOGICAL DESCRIPTION OF THE NORTHERN COAL-FIELD, ITS DYKES, AND OTHER PROMINENT FEATURES.

The outer boundaries of the great basin of the Coal-measures of Northumberland and Durham are well defined and explored (with the exception of a portion on the southern side) by the outcrop of the various beds around the northern and western sides—by the various sinkings and workings of the coal along the coast on the eastern side—and by the workings of the several collieries opened out on the southern and western sides of the coal-field. These are shown on the large Coal Trade Map exhibited, and on the reduced map annexed to this paper. On these the great coal-field basin proper is coloured dark. It reposes upon and is conformable to the Millstone Grit series of rocks, and it is covered, on the south-eastern side, by the Lower-new-red-sandstone and Magnesian-limestone. The Coal Trade sections on a large scale, viz.:—A, B, and C, and the sections 3 and 4 on a small scale, accompanying this paper, are illustrative of the regular coal-field.

We desire to call attention to the general map, and to the three other sections, Nos. 1, 2, and 5, on a small scale, which show the connection of the great coal basin with the other underlying and subordinate coal beds which are situated in the great series of deposits of the Carboniferous or Mountain-limestone formation, and which are, we assume, also connected with the lower coal beds of the Lothians, and south and west of Scotland generally.

The three Coal Trade sections, A, B, and C, and sections 3 and 4, exhibit generally, the various beds of coal occurring in the true Coal-measures. It is, of course, difficult to delineate all the different beds of coal accurately on a comparatively small scale, and especially the strata between each pit. All that has been attempted is to show the strata through which each pit has been sunk; between these sinkings approximate sections only can be given or arrived at, but no doubt can exist as to the character of the intermediate strata. They are essentially of the regular Coal-measures, designated in the Northern Coal District as coal, post, or sandstone, and metal or shale, with all their admixtures and variations of mineral composition.

Commencing at the northern outcrop, near the mouth of the Coquet,

and taking a circuit around the edges of the basin, the lowest coal beds crop out to the surface, resting on the Millstone Grit series, which are strictly conformable to the Coal-measures. From this point, and all along the western edge of the basin southwards, the coal beds, rising gently from east to west, consecutively crop out to the surface over the lands of Blagdon, Ponteland, the ancient commons of Throckley Fell, Hedley Fell, Lanchester Common, Wolsingham Common, Hamsterley, Evenwood, and Brusselton, crossing the Tyne near Horsley Wood, and the Wear to the west of Witton Castle.

At Ferry Hill, Westerton, Black Boy, Eldon, and Brusselton, the escarpment of the Magnesian-limestone is reached, and here covers the Coal-measures, resting upon them unconformably, forming prominent faces of quarries, &c., and running in a diagonal line from thence to the sea coast at South Shields and Tynemouth. The Coal-measures to the east of that line of escarpment, and along the Durham coast, being covered by the Magnesian-limestone. The southern termination of the coal beds from Brusselton direct eastward has not yet been clearly defined. In those collieries where the workings have been pursued to their junction with the Limestone, as at South Wingate, Cornforth, and Thrislington, the coal beds are terminated by passing upwards at a considerable angle into the unconformable Limestone beds, but these explorations have not extended far along the supposed southern boundary of the coal-field, though they are decisive as to the termination of the coal beds where they have been made.

Along the eastern boundary, the position of the coal beds from Warkworth to the southern extremity, near South Wingate, are pretty clearly defined by the various sinkings and workings of the different collieries along the coast. At the extreme northern edge of the basin the coal beds dip to the east or towards the sea; at Radcliffe and to Newbiggen they also dip eastwards; south of Newbiggen to Hartley, the declination is south-east. Then again, from Hartley to Tynemouth, the rise is about east. Along the coast, from South Shields to Marsden, after rising to the east, the coal beds begin to dip eastwards, and in Harton royalty a southern and eastern declination takes place towards the point of greatest depression, or bottom of the basin, east of Monkwearmouth. From thence southwards to Castle Eden, a distance of thirteen miles, and near the southern extremity of the coal-field, the declination continues eastward.

The foregoing are the general outlines of the boundaries and the dip of the coal-field proper along the sea coast.

Before describing the other subordinate coal beds within the great carboniferous series of rocks, we shall point out some peculiarities incidental to the coal-field proper.

Taking the sea coast as a datum line, and the high water level of the sea as a datum level, it will be seen by the sections exhibited that the lower beds of the Coal-measures approach the surface at a certain depth beneath the datum line at Warkworth, the northern extremity of the coal-field; and that at South Wingate (the southern extremity) they terminate at about the same distance below the sea level. Between the two extremes, the line of coast passes through a very great depression of the strata, designated locally a "swelly," and constituting that feature generally met with in coal-fields which is properly termed a *basin*. This greatest depression takes place near the town of Sunderland, where the coal beds are at a depth of 300 fathoms, or 1800 feet, below the level of the sea, and certainly 1000 to 1440 feet below the level at each extremity. The coal beds rise out of the swelly at Monkwearmouth from a depth of 1800 feet below the sea, to the westward, until they reach the crop of the coal at Hownes Gill, as shown by the Coal Trade section C, where the same beds crop out at an elevation of 740 feet above the level of the sea, showing a rise in the beds or strata of 2540 feet. From these facts it would appear, therefore, that a very large portion of the coal-field, none of which may be said to be explored, is covered by the sea. This depends, of course, upon the extent of denudation, and upon the covering of the unconformable Magnesian-limestone, which, near the point of the greatest depth of the Coal-measures, is probably 300 feet in thickness.

Taking the extreme depression of the strata at 1800 feet, the extent of coal-field being about 20 miles to the north and west, makes the angle at which the beds lie to be generally very moderate—about 1 in 40. There are some instances where the inclination is very considerable, but they are entirely attributable to the occurrence of slip dykes, and are consequently local disturbances.

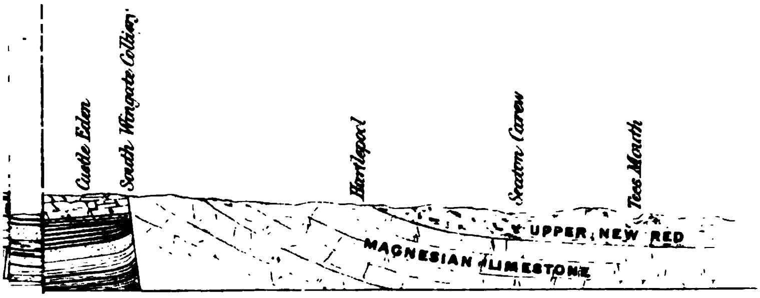
Two extensive and considerable slip dykes, or faults, cross the entire coal-field from east to west, viz., the great Ninety-fathom Dyke, crossing the coal-field and subjacent Millstone Grit and Mountain-limestone from the sea, near Cullercoats, on the east, to Tynedale Fell on the west. This dyke is evidently one of depression, the beds being thrown down to the north and bent over, at a distance of from 800 to 1000 yards from the dyke, the dip depending, apparently, on the

with beds lying above the lowest beds of the Scar-limestone series, there have been developed extensive coal beds in the North of Northumberland, at Scremerston, and in the south-west of the county at Plashetts. The former have been described by Mr. Boyd, and the latter by Mr. Wood, in Vol. XI. of the Transactions of the North of England Institute of Mining Engineers. These coal beds at present occupy a subordinate value in a commercial sense, compared with the coal seams proper. The section at Scremerston, however, exhibits several beds of coal, having an aggregate thickness of 90 feet; and they occur in that part of the Carboniferous series which is much older than the regular coal beds. Such a formation is certainly an occurrence well worthy the consideration of geologists. We would, therefore, refer to these two papers for further details on this subject.

As regards these coal beds, also, a question arises, whether they are not contemporaneous with the lower coal beds of the great western coal-fields of Scotland. In one of the papers above alluded to, Mr. Wood has given some sections, and has made some observations, illustrative of this view of the question, which are respectfully submitted to the consideration of the society. Two of these sections, showing the assumed position of the various groups of beds, are given in the paper attached to this communication, Nos. 1, 2, and 5. It is an enquiry well worthy of further investigation, as well as that of the coal-field of Canonbie, described by Mr. Gibsone, in Vol. XI. of the Transactions of the Minibg Institute, and which want of space in this communication will not allow us to notice, further than to refer to the paper itself.

We would briefly glance at the importance, in every point of view, especially geologically and commercially, of that series of deposits comprehended within the Carboniferons era, commencing with the Old-red-sandstone as a base, and ending with the Permian series. We pass through, in such era, strata containing all the coal, iron, and lead of Scotland and the North of England. These alone, which form only a portion of such series of deposits, are well worthy of the study and attention of such a body as the British Association visiting the Northern Counties. And as the complete series lies within the area of the counties of Northumberland and Durham, in directing the attention of the meeting to such an enquiry, we trust we are not overstepping the duty imposed upon us, when we undertook to lay before it some observations on the Coal, Coke, and Coal Mining in these Districts.

No. I.



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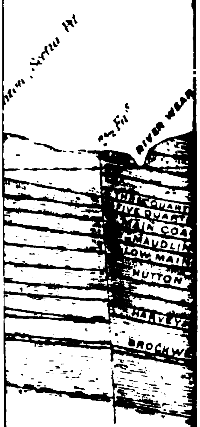

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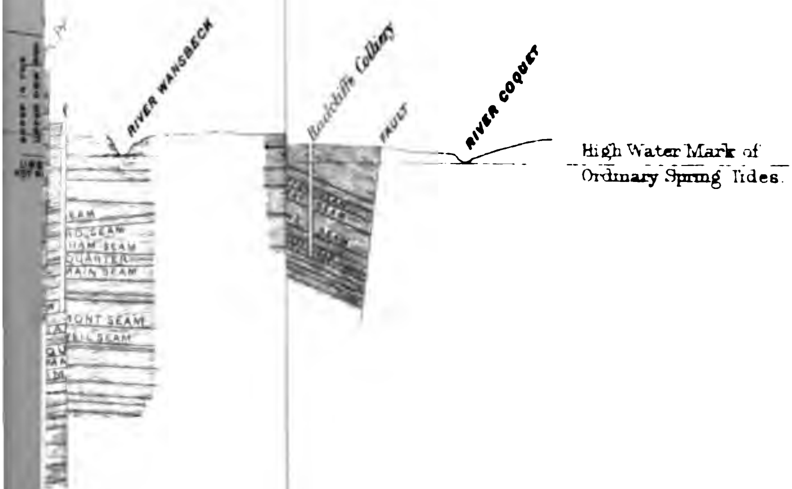

RIVER WANSBECK
Radcliffe Colliery
FAULT
RIVER COQUET
High Water Mark of
Ordinary Spring Tides.

No. 2.—ON THE ECONOMIC USES OF THE VARIOUS BEDS OF COAL IN THE NORTH OF ENGLAND COAL-FIELD.

The beds of coal of the Northumberland and Durham Coal-fields produce the following descriptions of coal, viz.:—

1. Household Coal.
2. Gas Coal.
3. Manufacturing Coal.
4. Steam Coal.
5. Coking Coal.

1.—*Household Coal* would probably be the description of coal first in request, and those beds which cropped out to the surface, and were most easily worked, would be first used, whether they were best adapted for domestic purposes or not. Hence we find it recorded in the earliest period of the coal trade, that all the beds were indiscriminately worked and used as household coal; their use depending, not upon their peculiar adaptation for that purpose, but upon the comparative facility with which such coal could be procured. As time progressed, and the means of working other beds were discovered, and when the various purposes for which coal was required also became numerous, then that description which was best adapted for the specific purpose for which it was required would be worked and used; therefore, at the time when *house firing* was mostly required, a description of coal was used as household coal, which, when burnt, left no residue, or produced few, if any ashes, particularly white ashes, and which gave out the greatest quantity of heat under those conditions, and burnt in a steady and uniform manner.

2.—When *gas* lighting was introduced, a coal was required which produced in its combustion the greatest possible quantity of gas, the purity of the gas being also an important object, together with cheapness.

3.—On the application of steam-driven machinery to our manufactories, a coal which produced the greatest amount of heat, without destroying the fire bars of the engine furnaces, and leaving as little residue as possible, or only a small quantity of white ashes, and therefore constituting an open burning coal, was preferred for steam engines. This was called *manufacturing coal.*

4.—When steam engines became more numerous, and, particularly, when the use of coal for steamboat engines became extended, a coal adapted for raising the largest quantity of steam, open burning, compact and hard, and not liable to break into small coal and form dust, and which, when used in long voyages and exposed to different temperatures of climate, did not fall into pieces, was required, then a class of coal called *steam coal* was in demand.

5.—Lastly, when the use of locomotive engines on railways was introduced for the conveyance of passengers, there was a statutory enactment made that coke only should be employed as fuel. An extraordinary demand then arose for *coking coal*, or that description of coal which produced the largest quantity of coke free from sulphur, and leaving no clinker on the grate bars, but which was open burning, or produced a small quantity of white ashes, to keep the fire bars from being burnt. Recently, however, the locomotive engineers have succeeded, to a considerable extent, in preventing the formation of smoke, thus rendering the use of coke comparatively unnecessary. Still there is a considerable demand for coke for locomotive engines, as well as for making iron and steel, and in malting, brewing, &c.

On referring to the synopsis of the several beds of coal produced by the Northern Coal-field, it will be seen that this coal-field produces all the various descriptions of coal required for the purposes enumerated above, and in some part or other it produces the best description of coal required for each specific purpose. For instance, taking the several purposes separately—

1. *Household Coal.*—The best household coal was for a long period of years produced from the High Main coal of the Tyne (C in the synopsis), the immediate colliery from which it was produced being Wallsend on the Tyne, and hence the origin of the designation "Wallsend," to distinguish the "*Best Household Coal.*" This coal was also produced at the various collieries of Percy Main, Walker, Heaton, Willington, &c., on the Tyne. It was not that coal of similar, or, indeed, as afterwards turned out, of superior quality, was not produced on the Wear and Tees, but the coal of such quality on the Wear being mixed with and sold with other coals of an inferior quality, no coal of that river, or, indeed, in the whole coal-field, bore such an excellent character or sold at such high prices as the "*Wallsends*" of the Tyne. Time, however, arrived when the Hutton coal seam of the Wear was sold unmixed with other coal; and, being found in the neighbourhood of Rainton, Lambton,

and Hetton of very superior quality, it was brought into the market as a *Wallsend* coal. The superior Wallsends of the Tyne being worked out, it took their place, and, up to the present time, has been sold as the best *Wallsend* coal. This coal is now produced from the Hutton seam (K) of the neighbouring collieries of Stewart, Lambton, Hetton, and Haswell. The only coal for a long period on the Tees approaching to the quality of the Wallsends of the Wear was *Tees* Wallsend, or the Five-quarter and Main Coal of the Black Boy Colliery (D and F); but, more recently, the Five-quarter seam (D) in the Hartlepool district has produced a coal approaching to the Wear Wallsends. Household coal, of second or inferior quality, is produced from the collieries of all the other localities, as shown in the synopsis. On the map these localities are unshaded, the localities for best coal being shown by lines crossed at right angles.

2. *Gas Coal.*—The best gas coal is produced from the Hutton seam (K), which also, as before stated, produces the best household coal; not that the chemical analysis of the coal is different, but the coal is of a less compact nature, liable to disintegration, and, as such, is not fitted or saleable as a first-class household coal, and, consequently, it is of less value for that purpose, but equally valuable as a gas coal. This kind of coal is obtained from the Felling, Pelaw, Pelton, Peareth, &c., Collieries, and from some of the lower seams on the Tyne. It is shown on the map by oblique lines at an angle of 45°.

It is also produced by the same seam on the Wear, and from the Brockwell seam (S) on the Tees.

3. *Steam Coal.*—The best coal for steam purposes is also from a tract of the Hutton seam, lying to the north of the Ninety-fathom Dyke in the Hartley district, and comprising almost all the coal north of that dyke, along the coast from Hartley, and to the crop of the coal in those districts, to Warkworth. It is a curious coincidence that the same bed of coal, the Hutton seam (K), is not only continuous throughout the whole extent of the coal-field, from Warkworth, in the north, to Haswell and South Hetton, in the south (nearly the southernmost extremity of the coal-field), but that it also yields the *best* description of three different varieties of coal, suitable for purposes not at all similar to each other, viz.:—the *best household*, the *best gas*, and the *best steam coal.* The locality of this coal is shown by perpendicular lines on the map attached to this report.

4. *Coking and Manufacturing Coal.*—The best coking coal is got from

the lower beds of the Tyne. Manufacturing coal (O P Q), either separate or mixed with a gas coal (K), is associated with it, and is obtained from the lowest seam in the Auckland district (S). This is what might be expected, as the properties of a good manufacturing coal, or coal for engines and manufacturing purposes, being very much what coke is applied to. The lower seams at Marley Hill (K and R), Garesfield, Wylam, Towneley, &c., are the seams which have produced the best coal for manufacturing purposes on the Tyne for years. They all produce a first-rate quality of coke.

The lowest seams at Etherley, Brancepeth, Black Boy, &c., are the seams parallel to the Garesfield or Brockwell seam (S), they produce also a first-rate quality of coke. These two series of beds produce the best description, and the great bulk of coke for the locomotives, and for the iron furnaces at Cleveland, whilst the second rate coke is produced from the Harvey or Beaumont seam (O), and from the washed small coal of the Hutton seam (K). The locality of the best description of coke is shown on the map by horizontal lines.

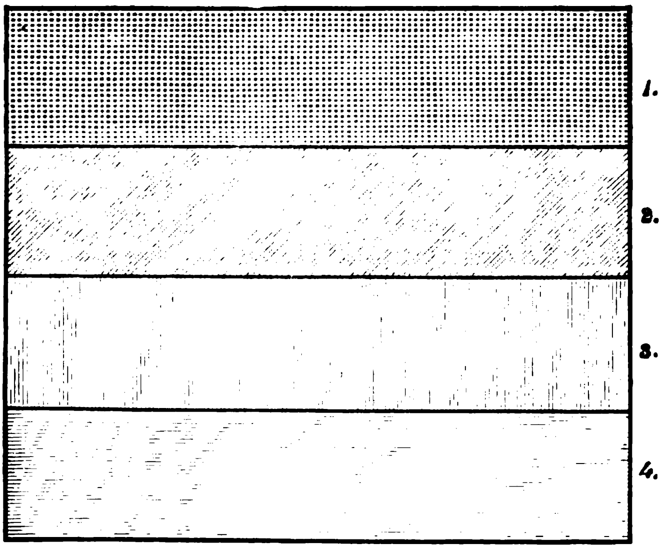
The Newcastle coal-field is essentially a bituminous coal deposit. It does not contain any anthracite, nor, with the exception of a thin bed in a limited locality, does it contain any cannel coal. Its specific gravity being from 1·2 to 1·5, and the quantity of carbon 72 to 75 per cent.

It is almost unnecessary, in a paper of this description, to enumerate all the different purposes to which coal is applied, or the important and invaluable uses of that mineral. Not only fireside comfort, but the manufacturing and commercial industry of the entire civilised globe is indebted, more or less, to its powerful effects, and the conveyance of almost the entire population of the world, whether travelling by sea, land, or water, testifies to its universal aid, whilst its chemical properties in distillations produce the most beautiful dyes that have yet been discovered.

It has been calculated that an acre of coal, 4 feet in thickness, produces as much carbon as 115 acres of full grown forest—and that a bushel of coal (84 lbs.) consumed carefully, is capable of raising 70,000,000 lbs. one foot high; and that the combustion of 2 lbs. of coal gives out power sufficient to raise a man to the summit of Mont Blanc. The aggregate steam power calculated at 83,635,214-horse power of Great Britain and Ireland alone, is calculated as equal to 400 million men, or equal to twice the power of the adult population of the globe; and by its aid the genius of the present generation is enabled to transport vessels of above 20,000 tons burden across the Atlantic in nine or ten days; and trains of

300 or 400 persons at the rate of 60 miles an hour—a performance which the combined efforts of the adult population of the whole globe would be unable to accomplish.

The various descriptions of coal, Nos. 1, 2, 3, 4, and 5, above referred to, are marked upon the Map of the Coal-field, thus



EXPLANATION OF WOODCUT.

1. *Household Coal.*—Indicated on the general map by lines crossed at right angles.
2. *Gas Coal.*—By oblique lines.
3. *Steam Coal.*—By perpendicular lines.
4. *Coking and Manufacturing Coal.*—By horizontal lines.

No. 3.—THE EARLY HISTORY OF COAL AND COKE, AND PARTICULARLY IN THE NORTHERN DISTRICTS.

The earliest record of coal in sacred history is contained in Leviticus (xvi., 12), B.C., 1490, in which the priest is commanded to take a "a censer full of *burning coals of fire*" and sprinkle incense thereon. It is quite possible, however, that here the word "coal" may mean charcoal, although the existence of coal in Syria is now placed beyond a doubt, as seams of coal crop out and appear at the surface, at various elevations, on the mountains of Lebanon, and a mine has been worked near Beyrout, 2,500 feet above the sea, where the seams are three feet thick.*

Job also makes mention of coals, and coal is mentioned elsewhere in early sacred history.

Early mention is made of coal (B.C. 371) under the name "*Lithanthrax*," by a Greek author,† as being found at Elis, and used by smiths. However doubtful the above references may seem, there can, however, be little doubt that the Ancient Britons (prior to the invasion of the Romans) used coal, although not referred to by the Roman writers. The numerous forests existing in Britain, before the Roman invasion, would naturally prevent the seeking of a substitute for wood; but, as the forests were cleared, coal, at the "outcrop" of the seams, would naturally be worked, in order to mitigate the severity of the climate. It has been proved that coal was worked partially by the Romans, not only by the discovery of tools near the stations on the Roman Wall, but *cinders* have also been frequently met with.

Again, Tennant refers to the circumstance of a flint axe being found at the outcrop of a seam of coal in Monmouthshire, and this would also tend to prove that coal had been worked by the Ancient Britons.

In A.D. 852, there is a record of the Abbey of Peterboro' receiving twelve cart loads of fossil, or pit coal.

For some long period after this, there is scarcely any record of the use of coal.

In A.D. 1180, there occurs in Bishop Pudsey's book (Bishop of Durham), a grant of land to a collier, for providing coals for the cartsmith at Coundon, in the county of Durham; similar grants being made at Bishopwearmouth and Sedgefield, in the same county.

* See Dr. Bowring's report.

† Theophrastus, B.C. 371.

In A.D. 1239, Henry III. granted a charter to the freemen of New-castle-upon-Tyne to dig coals in the castle fields; and, shortly after this, coal was sent to London.

Marco Polo mentions the use of coal in China in the 13th century, and it is supposed to have been used there much earlier.

In A.D. 1305, towards the end of Edward I.'s reign, considerable quantities of coals were used by brewers, smiths, &c.

This was followed by much complaint being made of the injurious effects of the smoke, and the burning of coal was prohibited, and, by commission from the King, fines levied to prevent it. Nothing, however, resulted from this prohibition, as 10s. worth of coals were used at the King's coronation, a few years afterwards.

In A.D. 1351, Edward III. granted a license to the freemen of New-castle to work coals without the town walls; and about A.D. 1367, coals were also worked in the neighbourhood of Winlaton, near Newcastle-on-Tyne.

Cockfield Fell Colliery is recorded as one of the early landsale collieries in the county of Durham.

In A.D. 1379, the first government tax was laid on coal.

In A.D. 1421, a duty of 2d. per chaldron was paid to the crown "on all coals sold to persons not franchised in the port of Newcastle." This duty having got into arrear, payment was demanded by Queen Elizabeth, and, in lieu of arrears, a duty of 1s. per chaldron was imposed, which was enforced to the time of Charles II., when it was settled on his natural son, the Duke of Richmond. In 1799, it was sold to the government for an annuity of £19,000, and ultimately repealed in 1831, after being continued upwards of 400 years. *This tax was peculiar to the Tyne.*

Queen Elizabeth imposed a tax of 5s. per chaldron on coals sent over-sea, to which King James I. added 3s. 4d. per chaldron, and an additional 1s. 8d. per chaldron on coals exported in foreign ships.

After the great fire of London the Lord Mayor was granted an impost of 1s. per chaldron for rebuilding the city, which was further increased to 3s. An additional tax by parliament of 2s. per chaldron was imposed in 1670, for the purpose of rebuilding fifty-two parish churches, and, in 1677, a further tax of 3s. was imposed, partly for rebuilding St. Paul's. The duties for rebuilding churches continued during Queen Anne's reign.

The taxes on coal during the 18th century underwent many changes, and in the great war the government duty was as high as 9s. 4d. per chaldron.

Various other duties have been from time to time enforced, which have

since all been repealed except the City and Orphan's Duty (payable at present) amounting to 1s. 1d. per ton.

In 1612, Simon Stentevant obtained a patent for making iron with *pit and sea coal,* wood having been previously used; at this time, with the use of *coal,* about three tons per week, per furnace, could be made.

In A.D. 1619, Dud Dudley used pit coal, in Worcestershire, for the manufacture of iron, having taken a patent for 31 years.

"Poor Dudley lost most of his property, and was imprisoned for debt; and when Cromwell came into power, he had the mortification of seeing a patent granted to one Captain Buck, for making iron with pit coal. He states that Cromwell and many of his officers were partners in the scheme, which, however, failed."

"Dudley does not seem to have been successful in his undertaking, and with him died, for a time, the art of making iron with pit coal."

In A.D. 1686, in Dr. Platt's History of Staffordshire, speaking of coal and its uses, he says, "for smelting, fining, and refining of iron it cannot be brought to do."

"It was not until 1713 that we hear of any further attempts in this way, when Mr. Darby, of Colebrook Dale, is referred to as smelting iron with pit coal. The process, however, must have been ill understood, and little known; for, in 1747, it is stated in the Philosophical Transactions, as a sort of curiosity, that Mr. Ford, from iron ore and coal, both got in the same place, makes iron brittle or tough, as he pleases; there being cannon thus cast so soft as to bear turning like wrought iron."

"While the change in fuel was being brought about, the manufacture declined so rapidly that, in 1740, the number of furnaces in England was 59, being only three-fourths of their previous number, and the annual produce was only 17,350 tons. As the use of coke became understood, the manufacture revived, so that, in 1788, the number of tons of pig iron produced was 61,300, as already stated; in 1796, the quantity was increased to 108,793 tons; in 1806, to 250,000 tons; in 1820, to 330,000 tons; in 1827, to 654,500 tons; in 1845, to 1,250,000 tons; and in 1851, to 2,500,000 tons. In this year, the exports of pig iron were upwards of 1,200,000 tons, besides tin plates, hardware, cutlery, and machinery, bearing a total value of £10,424,139."

"The locality of the manufacture has also been affected by the change of fuel. In 1740, Gloucester was the largest iron producing county in Great Britain. Sussex had the greatest number of furnaces; there were a few in Kent, and a few in the Midland Counties, and along the Welsh

borders. After the introduction of coke, the coal counties assumed a far greater importance in connection with iron than the woodland districts had done."

"*Coke*" was used about A.D. 1640, chiefly for drying malt (in Derbyshire).

Very little was done towards the application of coal to the manufacure of iron until 1713, when it was commenced at Colebrook Dale.

Swedenborg, an able mineralogist, says, in A.D. 1734, "the use of coke not brought to perfection."

A.D. 1763 appears to be the earliest period in which coke ovens are mentioned, and M. Jars, in a work published in 1774, gives a drawing* of "nine kilns at Newcastle, for destroying the sulphur and reducing coal to cinders and *coaks*."

In A.D. 1788, 61,300 tons of pig iron were made, of which 48,200 were melted with coke, and 13,100 with charcoal.

Also, in A.D. 1788, Dr. Ure speaks of several attempts to reduce iron ore with "*coaked*" coal; and, about A.D. 1800, coke ovens were to be found on the outcrops of the Brockwell coal seams, at Cockfield, Woodlands, Old Woodifield, near Harperley, and other landsale pits in the southern part of the county of Durham—and the coke was used for breweries and foundries.

About A.D. 1827, Birtley and Lemington Iron Works used coke, which was made from Pontop Hutton seam.

A.D. 1843 to 1846.—The coke trade in the northern counties may be considered as established previously to this date only at Garesfield, Wylam, and it was made from the Busty, Harvey, and Brockwell coal seams.

The above remarks must be taken only as a general summary of the history of coal and coke.

* A copy of this drawing is given in Mr. A. L. Steavenson's Paper on the Manufacture of Coke, in vol. viii. of the Transactions of the North of England Institute of Mining Engineers, in which paper, and in subsequent discussions in vols. viii. and xi. almost every detail on the manufacture of coke, by Mr. A. L. Steavenson, and others, will be found; and also a description of a patent oven by Mr. Ramsay.

No. 4.—BRIEF STATEMENT OF THE DEVELOPMENT OF THE COAL AND COKE TRADE UP TO THE PRESENT TIME, COMPRISING THE MORE IMPORTANT STATISTICS.

The recorded statistics, referring to this subject, prior to 1828, will necessarily be very concise and imperfect.

	Coastwise.	Foreign.	Tons.
In 1602, the vend from Newcastle was			190,600
1609, Newcastle vend ..	214,305	.. 24,956 ..	239,261
Sunderland „ ..	9,265	.. 2,383 ..	11,648
Blyth „ ..	855	.. — ..	855
1621 to 1622, Newcastle..	301,785	.. 43,755 ..	345,540

1622, the port of Stockton began to vend coals at the rate of 10 chaldrons per annum.

	Coastwise.	Foreign.		Tons.
1630, Newcastle	253,380	.. 36,542 ..		289,922
1660, Newcastle and Sunderland				537,000
1700, Do. Do.				653,000
1710, Newcastle			475,000	
Sunderland			175,000	
				650,000
1750, Newcastle and Sunderland				1,193,457

In 1861 Northumberland and Durham produced as follows :—

Tons vended.		Burnt or wasted.		Tons raised.	Total collieries.
21,277,570	+	500,000	=	21,777,570	271

The number of collieries being 13 less than 1860, but about one million more tons of coals raised in that year. The total number of collieries were :—

		Tons.
England	2,074 ..	63,870,123
Wales	481 ..	8,561,021
Scotland	424 ..	11,081,000
Ireland	73 ..	123,070
	3,052	83,635,214

And out of the £34,000,000 value exported from Great Britain, coals formed £20,908,803.

We annex statistics of vends of coals, coastwise and foreign, from 1791 to 1862:—

	Coastwise vend. Tons.	Foreign vend. Tons.	Total vend. Tons.
1791	1,814,661	264,944	2,079,605
1795	2,251,547	418,885	2,670,432
1800	2,381,986	138,089	2,520,075
1805	2,426,616	147,146	2,573,762
1810	2,783,404	50,922	2,834,326
1815	2,717,509	159,174	2,876,683
1820	3,246,885	158,340	3,403,225
1825	3,309,386	178,544	3,487,930
1830	3,289,241	341,062	3,630,363
1835	3,290,241	494,485	3,784,996
1840	4,391,085	1,196,299	5,587,384
1845	5,477,273	1,731,113	7,208,386
1850	6,295,570	2,176,115	8,471,685
1861	6,405,395	3,959,252	10,364,647
1862	6,090,609	4,044,181	10,134,790

Brought down from 1861.

			Tons.
Coastwise and foreign, from north by sea			10,364,647
By rail— house coal		65,014	
Gas coking, &c.	15,006	30,000	
Coke	33,960	67,930	
			162,934
			10,527,581
Consisting of—House coal		4,493,450	
Gas coal		1,717,000	
Steam small, and manufacturing coal		4,317,120	
			10,520,570

In 1810,* the county of Durham vend, and number of men employed, was pretty accurately ascertained, and resulted as follows, viz:—river and sea vend annually of 1,866,200 tons, and employing 7,011 men, from 33 collieries, by river and sea-sale, viz—

15 to the river Tyne.
2 jointly to rivers Tyne and Wear.
16 to the river Wear.
0 to the river Tees.

Watersale 33.

			Tons.	Men.
Landsale .. 25, viz.,	12 in Tyne and Wear district		59,360 ..	74
	23 in Tees district ..	..	146,552 ..	308
	35	Total landsale tons ..	205,912 ..	382
	33	River and sea-sale ..	1,866,200 ..	7,011
Total ..	68 collieries in county of Durham		2,072,112 ..	7,393

In 1854, by Hunt's Records, Northumberland and Durham,
Vend 15,420,615 tons.

Do., Collieries—	Tyne and Blyth ..	94
„	Wear and Seaham ..	30
„	E. & W. Hartlepool & Tees	60
		184
	Landsale in all districts	41
	Total	225 collieries.

Number of male persons estimated as being employed in coal mining, in 1854, by Hunt, is—

Durham	28,265
Northumberland	10,536
Total	38,801

* In 1810 the geographical boundaries of the coal-field of the county of Durham were described thus—

On the east, by pits of Jarrow, Pensher, Rainton, Crow Trees, and Ferry Hill.
On the west, by Wylam, Consett, Thornley, West Pits, and Woodlands.
On the north, by the river Tyne.
On the south, by Ferry Hill, Brusselton, and Woodhouses.

Which were taken as equal to 160,000 acres, the whole area of the county of Durham being put at 582,400 acres, and appropriated in area as—watersale collieries one-third, and landsale as two-thirds, which watersale coal tract was then estimated to contain 40,000 acres.

Its present increased boundaries have been described fully in No. 1 of this series.

In order to show the necessity of the further advance of science, it need only be stated that, by the Inspectors' Reports for 1851 to 1860, both inclusive, the average number of lives lost for the 10 years is 909 per annum. In Great Britain we have approximately, 3000 collieries, in which 250,000 persons are engaged, of whom nearly 50,000 are employed directly in Durham and Northumberland.

The number of people employed in the Northern Coal-trade may be approximately estimated as follows :—

	1862.	1863.
Men and boys employed underground	29,600	36,000
Do. above ground	7,900	9,700
Do. in shipping coal	1,300	1,600
	38,800	47,300
Seamen and boys employed in the coasting trade, not including those in oversea trade	22,500	25,000
Total	61,300	72,000

For the purpose of illustrating the rapid development of the coal and coke trade, more especially in the southern parts of the county of Durham, since 1828, we next give tabular statements of the vends of the Stockton and Darlington and West Hartlepool and Clarence Railways.

STOCKTON AND DARLINGTON RAILWAY.

	Coal and Coke Exported.	Coals and Coke Landsale, Household and Iron Works.	Lime and Limestone.	Ironstone.	TOTAL.
	Tons.	Tons.	Tons.	Tons.	Tons.
1. 1845.—The year before the opening of Witton Park Iron Works..	567,036	359,993	9,714	14*	936,757
2. 1846.—The date of ditto opening	444,527	428,614	38,139	31,831	943,111
3. 1851.—The year of the open- of Eston Mines ...	441,352	1,017,644	120,604	379,607	1,859,207
4. 1856.—Or last year... ...	219,591	1,557,624	299,788	875,199	2,952,202

* Sent from Middlesbrough to Witton Park Iron Works.

PROGRESS OF TRAFFIC ON STOCKTON AND DARLINGTON RAILWAY AND BRANCHES, FROM 1828 TO 1862, INCLUSIVE.

Year.	Coals and Coke Exported. Tons.	Coals and Cinders Landsale. Tons	Total Tons.		Sundry Lime and Stones. Tons.	
1828	65,046	64,739	129,785	—	9,834	
		Landsale and Manufactories.				
1838	420,802	233,985	654,787	—	27,911	
1845	—	—	927,029	—	—	
					Limestone and Ironstone, &c.	
1846	—	—	873,114	—	38,139	
1848	371,113	663,088	1,044,201	—	288,480	
1851	—	—	1,458,996	279,607	120,604	
1856	—	—	1,777,285	575,499	299,788	
				Ironstone.	Limestone.	Total.
1858	253,995	1,442,626	1,696,621*	977,575	363,082	1,340,657
1862	276,344	2,219,899	2,496,243	975,810	427,091	1,402,901

The total number of tons of coal and coke sent by the West Hartlepool and Clarence Railways:—

1838.—No means of ascertaining.

			Tons.
1848.—	Landsale	124,167	
	Export	411,180	
			535,297
1858.—	Landsale	434,437	
	Export	741,327	
			1,175,764
1862.—	Landsale	591,610	
	Export	960,163	
			1,551,773

And for the purpose of illustrating the progress of the district generally, we next attach the tabular statement of coal and coke traffic on the North-Eastern Railway.

* Coals, 1,104,451; Coke, 592,170 = 1,696,621 tons.

STATEMENT OF COAL AND COKE (DISTINGUISHING EACH) CONVEYED BY THE NORTH EASTERN RAILWAY IN THE FOLLOWING YEARS:—

	FOR SHIPMENT.				FOR LAN. SALE.				TOTAL COAL FOR SHIPMENT AND LANDSALE.		TOTAL COKE FOR SHIPMENT AND LANDSALE.		TOTAL COAL AND COKE.	
	COAL.		COKE.		COAL.		COKE.							
	Tons.	Cwts.	Tons.	Cwts	Tons.	Cwts.	Tons.	Cwts	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts
1851*	...	...	...	...	...	...	...	...	...	...	...	...	4,354,700	0
1855	2,717,242	13	83,266	18	2,045,112	6	586,043	5	4,762,354	19	669,310	3	5,431,665	2
1856	2,856,093	0	87,875	2	1,948,080	11	594,790	11	4,804,173	11	682,665	13	5,486,839	4
1857	2,796,543	0	124,919	13	2,005,513	7	633,877	6	4,802,056	7	758,796	19	5,560,853	6
1858	2,973,012	19	118,987	15	2,009,782	5	484,501	8	4,982,795	4	608,489	3	5,586,284	7
1859	3,065,058	11	97,366	2	2,062,538	17	410,285	3	5,127,597	8	507,651	5	5,635,248	13
1860	3,331,799	16	96,932	2	2,177,214	17	538,558	4	5,509,014	13	635,490	6	6,144,504	19
1861	3,544,345	18	132,181	10	2,291,077	8	481,735	10	5,835,423	6	613,917	0	6,449,340	6
1862	3,534,598	14	137,057	10	2,249,879	19	522,632	8	5,784,478	13	659,689	18	6,444,168	11
Total..	24,818,694	11	878,586	12	16,789,199	10	4,252,428	15	41,607,894	1	5,130,010	7	46,738,904	8

* For prior dates, unable to get statistics; besides, not the same lines under the same name.

In 1858, Mr. A. L. Steavenson, in the papers above referred to, estimated the coke made in the northern counties at two million tons, but this was considered to be a rather high estimate, on account of the quantity calculated for iron making, per ton of pig iron (175 instead of 160). For Great Britain the same authority estimated the make of coke at six million tons. Mr. T. Y. Hall, in Vol. II. of the North of England Institute of Mining Engineers' Transactions, estimated the area of coking coal at 160 square miles. It has been estimated that for each ton of coke made, about half a ton of water is used in cooling it.

The average analysis of coking coal is as follows :—

Carbon	84·92
Hydrogen	4 53
Nitrogen	0·96
Sulphur	0·65
Oxygen	6·66
Ashes	2 28
	100

The effect of coking being to drive all off except carbon, 31¼ per cent. has been given as a good average by heap burning. By close ovens, from 50 to 60 per cent., or 5 to 3, can be obtained.

The present make of coke in Northumberland and Durham, as ascertained from the principal manufacturers, is estimated to be 2,519,545 tons per annum, the capabilities slightly more, say 2¾ million tons as a maximum; and thus, for the present *make* of coke alone, there is required an annual consumption of 1000 acres of a 4-feet seam of coal.

The following analysis of coals and coke may be interesting :—

	No. 1. Hutton Seam, best Household Coal of the District.	No. 2. Low Main Seam, best Steam Coal of the District.	No. 3. Anthracite, best Steam Coal in Wales (Smokeless).	No. 4. Coke from Durham Coal.
Carbon	84·284	78·690	92·34	93·150
Hydrogen	5·522	6 000	3·00	0 721
Nitrogen	2·075	2·370	0·58	1·276
Oxygen	6·223	10·068	2·57	0 905
Sulphur	1·181	1·509	...	...
Ash	0·715	1·868	1·51	3 948

No. 5.—ACCOUNT OF NEW DISCOVERIES AND THEIR APPLICATION CONNECTED WITH THE COAL AND COKE TRADE.

Wooden railways were introduced between 1632 and 1649, and were in general use between 1670 and 1860.*

In 1671, we have records of Sir Thomas Liddell's first staith bills, showing that coal was then led in wagons to the river Team, near to the river Tyne.

1714, only three atmospheric engines were employed.

Prior to 1741 coals were sold in the same state as they were produced from the pit. At this time, however, the system of screening was introduced by William Brown; and, although this produced a superior article, it may be questioned whether or not it was an advantage to the coal trade at that period, for it was the means of causing immense quantities of small coals to be burnt to waste, as being unsaleable.

In 1760, the steel mill was invented.

In 1777, Curr, of Sheffield, introduced underground rails in lieu of sledges.

In 1794, cast iron rails were partially used on the Walbottle Railway.

In 1798, the invention of lighting by gas was introduced by Murdoch, at the Soho Works of Bolton and Watt.

In 1812, the steamboat was introduced on the river Clyde, by Dr. Bell, and now screw colliers are taking coals regularly from the river Tyne to London, and using about 4,000 tons of coal each per annum. They carry from 700 to 900 tons each, and generally complete the voyage in one week.

In 1815, malleable iron rails began to be used instead of cast iron.

Coke making was first begun by open heaps and then by close ovens. Coke ovens are now generally flued, and have tall chimneys to carry off the smoke. Coke ovens are also patented of all shapes, but the round oven is almost universally adopted. Mr. B. Thompson, in a paper on his inventions, claims priority in changing the shape of coke ovens from round to oblong, and for improvements in mode of erection. The use of hose instead of pails, in the application of water for cooling, was a subsequent invention.

* See an excellent treatise on Railways, by Nicholas Wood, Esq., first published in 1825.

For the principal inventions and patents in connection with coke ovens, we refer the members to the papers by Mr. A. L. Steavenson and others, in the Transactions of the North of England Institute of Mining Engineers, Vols. VIII. and IX.

To the late Mr. Blackett, of Wylam, is due the credit of showing that the locomotive engine was practicable on railways, about 1813.

In 1814, the first improved locomotive, by George Stephenson, was introduced.

Horses generally were used as the means of traction underground until about 1820, when steam power gradually began to be substituted.

Locomotive engines are now used to such an extent that mineral trains, from the South Durham coal-field, are conveyed to London, taking only about 17 hours. The engine powers are of from 450 to 500 horse-power each, and take loads of 350 tons as far as York.

The question of underground locomotives being introduced is now becoming of great importance; for example, we have the underground railway in London, and an experimental one at a colliery close to Newcastle, by Mr. T. M. Jobling, one of the members of the Institute of Mining Engineers at Newcastle.

In the year 1815, the Davy-lamp was introduced.

In 1825, the first public railway (viz., the Stockton and Darlington) was opened for conveyance of coals, minerals, and passengers, and the motive power first used was horses and subsequently locomotive engines. The first, or No. 1 engine, which ran on this railway, is still to be seen in front of the station at Darlington.

Boring by steam, with and without iron rods, forms an important element amongst recent inventions. With this may be mentioned that of boring with ropes, which has been done to the extent of 18 inches diameter and upwards of 200 fathoms deep, an example of which may be seen at Messrs. Bolckow and Vaughan's, Middlesbro' Iron Works, by those gentlemen of the Association who make the visit to the Cleveland district. The engine and apparatus of this boring having been made by Messrs. Mather and Platt, of Oldham, near Manchester. The section of this boring will be exhibited to the Association on this occasion.

A very interesting paper was read on machinery for boring stratified and other rocks, by Mr. George Simpson, before the Institute of Engineers in Scotland, in 1861. In this case iron rods were used.

For information on the mechanical means of ventilation by fans, exhaust and force pumps, we refer to the late Mr. Thos. J. Taylor's

paper, read before the Mechanical Engineers, in 1859. For pumping by machinery, and various kinds of pumps, we will refer you particularly to the same paper.

Safety Cages.—In this class we may mention that Fourdrinier's was introduced about 1845; then followed White's, Grant's, Owen's, Aytoun's, Calow's, and a great many others. This question is, to a certain extent, unsettled.

On the subject of tubs in shafts, we beg to refer to Mr. T. Y. Hall's paper, read before the Institute of Mining Engineers. See Vol. II.

Coal cutting by machinery or compressed air, now forms an interesting subject; and papers hereon, in reference to one at work near Leeds, will be found in Vol. XII. of the Transactions of the Mining Engineers Institute.

The most prominent feature in the changes of the coal trade, more particularly on the river Tees, was the discovery, in 1848, of the Cleveland ironstone, as its bearing on the coal trade of that district was so direct and important.

As the treatment of ironstone and its manufacture belongs to another section, we will, for illustration, take east of Bishop Auckland, and adjoining the river Tees. For instance, in 1846, the first blast furnace was erected at Witton Park, in the neighbourhood of Bishop Auckland.

From 1846 to 1857, a period of 11 years, we have 34 new furnaces, and now, 6 years more, there are 52, all lying to the east of Bishop Auckland, and connected directly with the Tees ports, or nearly one-half of the whole blast furnaces in the North of England; besides the fact, that each furnace averaged fully one-third greater yield in 1857 than in 1853, and now fully double that of 1853.

The *direct* bearing on the Tees coal district, by these 52 new blast furnaces, erected in the last 15 years, is to require at least three million tons of coals annually, or, about 600 acres of a four-feet coal seam more than in 1846, so that any calculation of the duration of the Northumberland and Durham Coal-fields must be subject to the rapid increase, or otherwise, in the iron manufacture, as 600 acres per annum extra requirements have all arisen in the last fifteen years, and the consumption of coal in the whole of the North of England, by blast furnaces or pig iron manufacture, would not be less than 1150 acres annually, or 5¾ millions of tons, if all the present furnaces were in full blast. If the gross make of pig iron be taken at five million tons, we have a requirement of nearly 3000 acres of a coal seam 4 feet thick, per annum.

In 1853, was the celebrated "Boghead Coal" trial, to determine whether it was coal or not. This mineral, compared with anthracite and cannel coal, certainly shows a great difference in analysis.

At the Royal Society's meeting in Edinburgh, on the 6th of February, 1855, they passed a resolution "That, in the present state of science, it is *impossible* to determine *what coal is*" ! ! *

1863.—The present length of railway underground, 1260 miles.

* On the authority of a lecture on "Coal, Corn, and Cotton, the three Kings that rule the World," delivered on the 17th December, 1862, by H. Cossham, and afterwards published, it is stated, that at a meeting of the Royal Society of Edinburgh, held on the 6th February, 1855, a resolution was passed, stating "that in the present state of science it is impossible to determine what coal is." Since the British Association Meeting in Newcastle, in 1863, this has been called into question by one of the members of the Royal Society, who states that no such resolution was passed or recorded in the minutes of the Royal Society.

No. 6.—SINKING OF PITS, AND DRAINAGE OF MINES.

Detailed statements of the most approved methods of sinking, may be met with in the Mining Institute Transactions, Vol. V., where the cases of Murton, Seaton, Ryhope, &c., are referred to.

Apart from the use of more powerful machinery, not much improvement has been made in the sinking of pits during the last thirty or forty years.

About 1795, cast iron tubbing, for damming back the large feeders met with in sinking, began to be generally used.

At first they consisted of circular rims, the full size of the shaft; but the late Mr. Buddle introduced segments, which were more manageable.

These segments, on being properly wedged, formed a complete barrier to the passage of water.*

It may be here remarked, that the metal tubbing, in upcast pits, in the course of a few years becomes converted into a substance closely resembling plumbago, and, in this state, is of course incapable of resisting the pressure of water behind it, hence we hear frequently of accidents occurring owing to the bursting away of the segments, thereby endangering the mine, both by the large influx of water and derangement of the ventilation.

By a very simple process, however, this danger may be entirely obviated; the remedy being merely to protect the metal by means of firebrick, or other casing, against the action of the sulphurous acid and other products of combustion.

The chief difficulties met with in sinking arise—

1. From quicksands, immediately below the surface.
2. From quicksands underlying the Magnesian-limestone.
3. From large feeders, met with in sinking through the Magnesian-limestone, and many of the Coal-measure-sandstones.

1st. The quicksands lying immediately below the surface are generally dealt with by piling; and, when the water is comparatively trifling, this is a very easy process.

* On completion of this casing, the pits in which metal tubbing is used, are rendered perfectly safe against inundation, arising from the bursting away of the segments; it having been proved (at Haswell Colliery, remarkable for its hot upcast shaft) that, after a period of about twenty years (during which the tubbing has been protected), it is in all respects as sound and perfect as at the time when first put into the pit.

At Framwellgate Moor, upwards of twenty fathoms were piled through; the pit having been commenced at 30 feet diameter, and ultimately, after 10 tiers of piling, a diameter of 14 feet was obtained.

2nd. The friable sandstone, underlying the Magnesian-limestone, is of a more difficult nature, owing to the feeders of water in it being so very considerable; and also to the circumstance that there is a difficulty in driving piles, masses of indurated sandstone being frequently met with.

Occasionally, a very large expenditure has been necessary in sinking through this sand; the feeders met with in it, and the superincumbent Magnesian-limestone, in Murton Colliery (about 20 years ago), being upwards of 9,000 gallons per minute, at a depth of 540 feet, and required steam power, amounting to 1,584 horses, before the passage through could be successfully accomplished.

The Magnesian-limestone, owing to its porosity, and the underlying friable sandstone, constitutes an excellent reservoir for water; hence sinkings have been made through it into this sand at Humbleton Hill, Fulwell, and Cleadon Hills, during the last few years, from which a supply of pure and excellent water is obtained for the towns of Sunderland, South Shields, and neighbourhood.

3rd. Large feeders of water, as remarked above, have been met with in the Magnesian-limestone, and also in many of the sandstones overlying the High Main seam of the Tyne.

The most remarkable instance is in the sandstone locally called the "Seventy Fathom Post," in which from 1,500 to 2,000 gallons per minute have been frequently encountered.

It is found generally that all these feeders gradually subside, owing to the constant pumping at the various collieries in the district.

No. 6.—DRAINAGE OF MINES.

As a general rule, the strata in the mines in Durham, underlying the Magnesian-limestone, contain very little water, the distance being so considerable between the bottom of the limestone and the seams of coal; and, also, from the fact of the sandstones passed through being comparatively compact and capable of holding little or no water.

It is found, however, in more shallow mines, that frequently very considerable surface feeders have to be drawn, varying from 400 to 1500 gallons per minute.

At the Hartley Pit (where the accident occurred last year) the quantity of water drawn to the surface was about 1200 gallons per minute, by an engine of 300-horse power, and from a depth of 600 feet.

Walbottle and Wylam are also equally remarkable for the large quantities of water met with, being in each case upwards of 1200 gallons per minute.

The general cost of pumping water from the Northumberland and Durham mines, exclusive of interest and redemption of capital, is about one farthing per ton of water raised per 100 fathoms.

In the cases of Walbottle and Wylam Collieries, the water drawn exceeds that of the weight of coals, in the ratio of 15 to 1.

For details of this subject, we beg to refer to the Mining Institute Transactions.

No. 7.—MODES OF WORKING.

The ordinary mode of working the coal seams, in the early period of coal mining, was to get as much of the coal as could possibly be done, leaving a pillar just sufficient to support the superincumbent strata, so as to secure the safety of the men working the seam; and, where practicable, to take out all the coal. Where pillars were left, attempts were afterwards made to work off a portion of this pillar, or "robbing" as it was technically termed, which generally resulted in producing a "creep" or "thrust," and so destroying the remaining coal almost entirely, or so crushing it as to render it unprofitable to work.

The late Mr. Buddle, perceiving the evil effects of this mode of working, commenced removing the pillars entirely, simultaneously with working the whole coal, as a system; thus leaving no support to the roof, which immediately fell, and thus relieved the pressure from the adjoining pillars.

This system, with various modifications, has been in operation up to the present time, the material difference being that a much larger description of pillar is now left than formerly, thus forming a sort of connecting link between the "board and wall" system and that of the "long wall."

The latter mode of working has been adopted in Northumberland and Durham at several collieries; but much depends on the nature of the roof and thill or underlying stratum of the seam of coal, and it has been generally found, after trying the "long wall" system, more expedient to form large pillars, which has had the effect of improving the coals, both as regards size and produce, when such pillars are worked.

It may be here remarked, that by the board and wall system, all coal of the entire coal-field can be obtained, none being wasted in the mine.

The extraordinary increasing demand for small coals for foreign and coking purposes renders this description of coal now of very great importance; whereas formerly, when there was no such demand, enormous quantities were annually consumed and wasted.

A reference to the Transactions of the Mining Institute, Vol. I., p. 239, will exhibit in detail all information connected with the subject.

Attempts have been made, from time to time, to supersede manual labour in the working of coal, and although those have only proved partially successful, still it is obvious that some means will be adopted

shortly to prevent the serious waste of coal entailed by the use of manual labour, especially in the tender and thinner seams. This important question has lately been examined into by Messrs. Daglish and L. Wood (see Mining Institute Transactions, Vol. XII., page 63), who report favourably on the machine invented by Messrs. Donesthorpe, Frith, and Hedley, and which is now in operation at the West Ardsley Mine, near Leeds.

The power adopted is compressed air, which is produced by an engine of 30-horse power. Metal pipes, to convey which, 4½ inch diameter, are taken down the pit, and thence 2½ inch pipes to the place where the machine is worked.

This machine has not yet been sufficiently tried to determine the economy of its use or otherwise; but Messrs. Daglish and Wood report "that the introduction of machines will relieve the miner (in low seams especially) of the more arduous, painful, and monotonous portion of his labour."

Another indirect advantage is, that as the compressed air is exhausted with very great rapidity, a very low temperature is produced; thus "aiding greatly the efficient ventilation and general sanitary condition of the mine."

This subject will undoubtedly be further prosecuted; the objects to be obtained being so important, viz.:—Saving of labour, prevention of waste, as compared with the present system (especially in the tender and thinner seams), and introducing a new ventilating power; we may hope, therefore, that this important matter will receive that attention which it so well deserves; and we are informed that the Hetton Coal Company has erected an experimental engine to test the principle and mode of working such engines.

No. 8.—VENTILATION AND LIGHTING OF MINES.

The ventilation of coal mines has been effected in various ways; a general summary of which is as follows:—

1st. *Natural Ventilation*, in which no artificial means are employed, advantage being taken of the direction of the wind, or other natural causes, and of the ascending power given by the heat of the workmen in the mine to the return current, and also by the heat given out by the increased temperature of the mine itself.—(*See inquiry into the Steam Jet, Vol.* I. *Transactions of Mining Institute.*)

2nd. *By Waterfall.*—This had the effect of causing a considerable current, but was objectionable, as the water was again to be raised to the surface, but it is used on extraordinary occasions to produce a current of air, in cases of accident or interruption to the ordinary modes of ventilation.

3rd. *Mechanical Ventilation*, by air-pumps worked by steam engines.

4th. *Steam Jet.*

5th. *Furnace.*

Prior to 1760, the *internal* ventilation of mines was carried forward by causing a current of air to circulate round the places in which the men were working, the intermediate space being left without ventilation. In this case, on any sudden fall of the barometer, or leakage of stoppings, gas was diffused into the passage roads of the mine, and on meeting the first light an explosion ensued.

Mr. Spedding, of Whitehaven, perceiving the objection of not ventilating the intermediate space of the mine, introduced the system of "*coursing or shething*," the simple meaning of which is to ventilate, as far as practicable, the whole of the mine. This had the effect of preventing the accumulation of gas in those parts of the mine from which the coal had been excavated, but the result was, that the distance to be travelled by the air current (and the consequent resistance) was so greatly increased, that a very trifling amount of ventilation was obtained.

It was also about the year 1760 that the "Steel Mill" was introduced; the object of which was to produce sparks, by holding a piece of flint against the revolving periphery of a wheel, the rim of which was steel.*

* This mode of ventilation is generally used in those mines the entrance to which is by an adit, or level, from the surface.

This instrument, although explosions did occasionally take place with it, was used in fiery mines, up to the introduction of the Davy-lamp in 1815.

About the year 1818, the system of "splitting" or dividing the current of air into several sections, was introduced; each of which ventilated its own district, and then passed direct to the furnace; the result was, that the distance to be travelled by the respective currents was much diminished, and an improvement, both in the quantity and purity of the air effected.

Davy's and Stephenson's lamps came into operation in 1815, by which a new era was introduced in coal mining, as those deep and fiery mines could now be worked, which could not be done under the old system.

Various committees of the Houses of Lords and Commons have, at different times, been appointed on the subject of the prevention of accidents in coal mines.

In 1835, a committee, of which Mr. Pease was chairman, reported as follows:—"Your committee regret that the results of this inquiry has not enabled them to lay before the House any particular plan by which the accidents in question (Mines) may be avoided with certainty; and in consequence no decisive recommendations are offered."

In 1839, a committee was appointed at South Shields (in consequence of a serious explosion at St. Hilda's Colliery) and an able report was published in 1843.

In 1845, Sir H. De la Beche and Dr. Lyon Playfair were appointed by government to institute an inquiry into the causes of accidents in coal mines. These gentlemen recommended the compulsory use of safety-lamps in all fiery mines, and the appointment of government inspectors.

In 1849, a committee of the Lords was appointed, who directed attention to the evidence adduced, especially as regarded the appointment of inspectors, the improvements in safety-lamps, and ventilation generally, and also devoted especial attention to the precise action and power of the steam jet, as a ventilating agent compared with the ordinary furnace.

At the same time, Professor Phillips and Mr. Blackwell were appointed to investigate and report on the ventilation of mines.

In 1851, government inspectors were appointed.

The number of deaths from explosions in Durham and Northumberland, from 1755 to 1815, that is, to the time of the safety-lamps being used, was 734, and to 1845 the number was 968, and from 1851 (the

commencement of the act appointing inspectors) the number of deaths has been at the rate of 161 per annum.

These results may appear paradoxical; but it must be remembered that not only has the production of coal been very largely increased, but the fiery and dangerous mines, which could not be worked prior to the introduction of the safety-lamp, have since that time being extensively brought into operation.

In the year 1813, when a very serious accident had taken place at Felling Colliery (resulting in 92 deaths), the late Mr. Buddle addressed a letter to a committee formed at Sunderland, of which Sir Ralph Milbanke was chairman, in which, after describing the various systems of ventilation practised at that time, he stated that the standard ventilation was from 2000 to 3000 cubic feet per minute in each air channel.

This quantity has been progressively increased, arising chiefly from—

1. Increase of furnace power.
2. Enlargement and increase in number of the air-courses.
3. Increase of the number of splittings or division of the main current into separate currents.

An instance of the ventilation of Hetton Colliery (one of the largest in the county of Durham) may be interesting, as contrasted with the ventilation of former periods, furnished by Mr. Daglish, the viewer of Hetton Colliery.

Account of the Quantity of air at the Hetton, Elemore, and Eppleton Collieries, as measured, Jan., 1863 :—

HETTON COLLIERY—*Hutton Seam.*		
North-way	46,000	
South-way	22,000	
East-way	20,000	
Engines	28,000	
		116,000
Main Coal Seam.		
North-way	30,000	
West-way	3,000	
South-way	12,000	
		45,000
Low Main Seam		15,000
Total Quantity at Hetton... ...		176,000

Elemore Colliery—*Hutton Seam.*

West-Way	31,570	
East-way	23,260	
Engines	11,000	
		76,830

Main Coal Seam.

West-way	13,000	
East-way	3,150	
Engines	10,000	
		26,150
Low Main Seam		12,000
Total Quantity at Elemore ...		104,000

Eppleton Colliery—*Hutton Seam.*

Main Air Current	63,000	
Boilers	25,000	
		88,000
Main Coal Seam		75,000
Low Main Seam		3,000
Total Quantity at Eppleton ...		166,000

In the *Main Coal Seam* the boilers are fed with return air.

Total.

Hetton	176,000
Elemore	104,000
Eppleton	166,000
	446,000

SUMMARY.

	Downcast Shaft.		Upcast Shaft.						Coals Consumed.						Ventilating Column, &c.				
																Tempera-ture.			
Colliery.	Name of Pit.	Diameter.	Name.	Diameter in Feet.	Net Area in Feet.	Velocity in Feet per Second.	Quantity of Cubic Feet per Minute.	Water Gauge.	Number of Furnaces.	Coals consumed per 24 Hours in Tons.	Number of Boiler Fires.	Coals consumed per 24 Hours in Tons.	Total Coals consumed per 24 Hours in Tons.	Tons Weight.	Depth in Feet.	Downcast.	Upcast.	Ventilating Column in Feet.	Horse-Power.
Hetton	Minor	11·5	Blossom ...	14·00	182	22	176,000	1·5	4	19·6	3	16	35·6	1115	900	45°	250°	260·1	109·3
Elemore ...	George	12·5	Isabella......	8·75	60	29	104,000	1·0	2	8·5	2	10	18·5	770	780	42°	300°	265·2	66·2
Eppleton ...	Jane	12·5	Caroline ...	11·15	95	29	166,000	2·0	2	8·5	6	28	36·5	1115	1044	50°	200°	257·0	98·0

To produce the foregoing results, the combined furnace power is calculated to be equivalent to the effect which would be obtained by an exhausting engine of 268½-horse power.

Although this is a very great increase of ventilation, as compared with former times, still it must be borne in mind that, as the resistance to the passage of air in mines increases as the squares of the velocity, the *power* necessary to produce such increased velocity (*cet. par.*) is as the *cube* of the velocity.

Consequently, to *double* the quantity of air circulating in a mine, the size of the air passages, and all other circumstances remaining the same, it will require *eight* times the power, or in the case of Hetton Collieries, 2148-horse power.

It may be remarked generally, that many means of ventilation have been devised from time to time, but it has been found that rarefaction, by the use of the ordinary furnace, possesses the advantages of

Greater cheapness,
Regularity,
And efficiency

over all other systems.

With respect to the lighting of mines, the general practice is to use the unprotected light in the "*Whole*," or first working of the mine; where blasting is necessary, and in removing the pillars, or second working, safety-lamps are used, as the ventilation cannot be so perfectly carried forward as in the "*Whole Mine.*"

Generally, it may be remarked that good ventilation, by whatever means produced, with the judicious use of the safety-lamp, is the only means of preventing the recurrence of those fatal accidents which have caused such disastrous destruction of human life and property.

In order to obtain a detailed account of ventilation, we have to refer to the papers on this subject in the Mining Institute Transactions, in Vols. I., III., VI., by Mr. N. Wood, the late Mr. Thos. J. Taylor, Mr. Longridge, the late Mr. Wales, Mr. Atkinson (the Government Inspector of Durham), Mr. Daglish, Mr. Armstrong, and others, who have theoretically and practically investigated this very important subject.

The following analyses of inflammable gases in mines were made by Professor Playfair and Dr. Richardson :—

	Wallsend Colliery. Bensham Seam.		Jarrow Colliery. Bensham Seam.		Jarrow Colliery. Low Main Seam.		Hebburn Colliery. Bensham Seam.		Killingworth Colliery. High Main Seam.		Gateshead Park Colliery. Low Main or Hutton Seam.
Carburetted Hydrogen	77·5	...	83·1	...	79·7	...	91·8	...	82·50	...	94·20
Nitrogen	21·1	...	14·2	...	15·3	...	6·7	...	16·50	...	4·50
Oxygen...	—	...	0·6	...	3·0	...	0·9	...	1·00	...	1·30
Carbonic acid	1·3	...	2·1	...	2·0	...	0·7	...	—	...	—
	99·9	...	100·0	...	100·0	...	100·0	...	100·00	...	100·00

No. 9.—THE UNDERGROUND CONVEYANCE OF COAL.

In the early period of the history of coal mining, the conveyance of the coal underground bore no comparison with that which it does at the present day. Previously to the introduction of the steam engine, mining for coal was confined to pits of inconsiderable depth. The sinkings were numerous, and the distances which the coal was conveyed from the place where it was excavated to the bottom of the pits was inconsiderable; and within the recollection of the present generation, the mode of conveyance was confined to sledges, on which the baskets of coal were placed, and drawn by ponies or horses, and in several instances, especially in Scotland, carried upon the backs of women, from the workings to the bottom of the pit, and sometimes even up the shaft to the surface. When the coals were not carried to bank in this manner, they were drawn by whimseys or gins or by water wheels.

After the introduction of steam engines, and when it became necessary to sink deeper for coal, tramways were introduced (in 1777), and superseded the use of sledges in conveying the coal from the workings to the bottom of the shaft. The coals were then drawn to bank by steam engines.

Afterwards edge rails were introduced above-ground, and they were likewise adopted under-ground, and were first of all employed to convey, in single trams, the coals from the face of the workings to the bottom of the shaft; subsequently, when the workings became more extended, the coals were conveyed by single trams to central stations, and thence in trains of from two to four along the main road to the bottom of the shaft.

When sledges were used, baskets (*corves*) made of wicker work were placed on them, and so conveyed to the shaft; and even when wheel carriages were first adopted, sledges were still used in the vicinity of the workings, and stations were fixed upon, and small cranes employed to lift the baskets or corves upon the carriages, and they were so conveyed from the stations along the main roads to the shaft.

After small wheel-carriages were introduced, the same arrangements were pursued at the stations, cranes being still used to lift the baskets and place them upon larger carriages, or "*rolleys*." Two, three, or four baskets being placed upon one rolley, and so conveyed to the shaft.

Ponies were used for single trams, and powerful horses for the wagons or rolleys on the main roads.

When baskets or corves were used, which was the practice for several years, they were drawn up the shaft by steam engines; but, as they were thus subjected to great wear and tear from the sides of the pit, and were also themselves productive of great injury to the sides of the shaft, various contrivances were adopted to remedy this expense. At last a plan, previously used in the collieries of the Midland Counties, of placing timber slides in the shafts, and of drawing up and down the shaft a platform or cage, made to work within such slides, was adopted, at the South Hetton Colliery, by Mr. T. Y. Hall, by which means the wear and tear of the sides of the shaft and of the baskets or corves was avoided. Since then tubs, or boxes of timber or iron, have been almost universally used, which are fitted up with wheels adapted for the round topped cast or malleable iron rails, not only throughout the workings but from the stations to the bottom of the shaft.

By this mode the coals are brought out of the working places in single tubs, and are drawn by ponies to the stations, from whence they are taken by fixed steam engines, self-acting inclined planes, or horses, from the stations to the shaft.

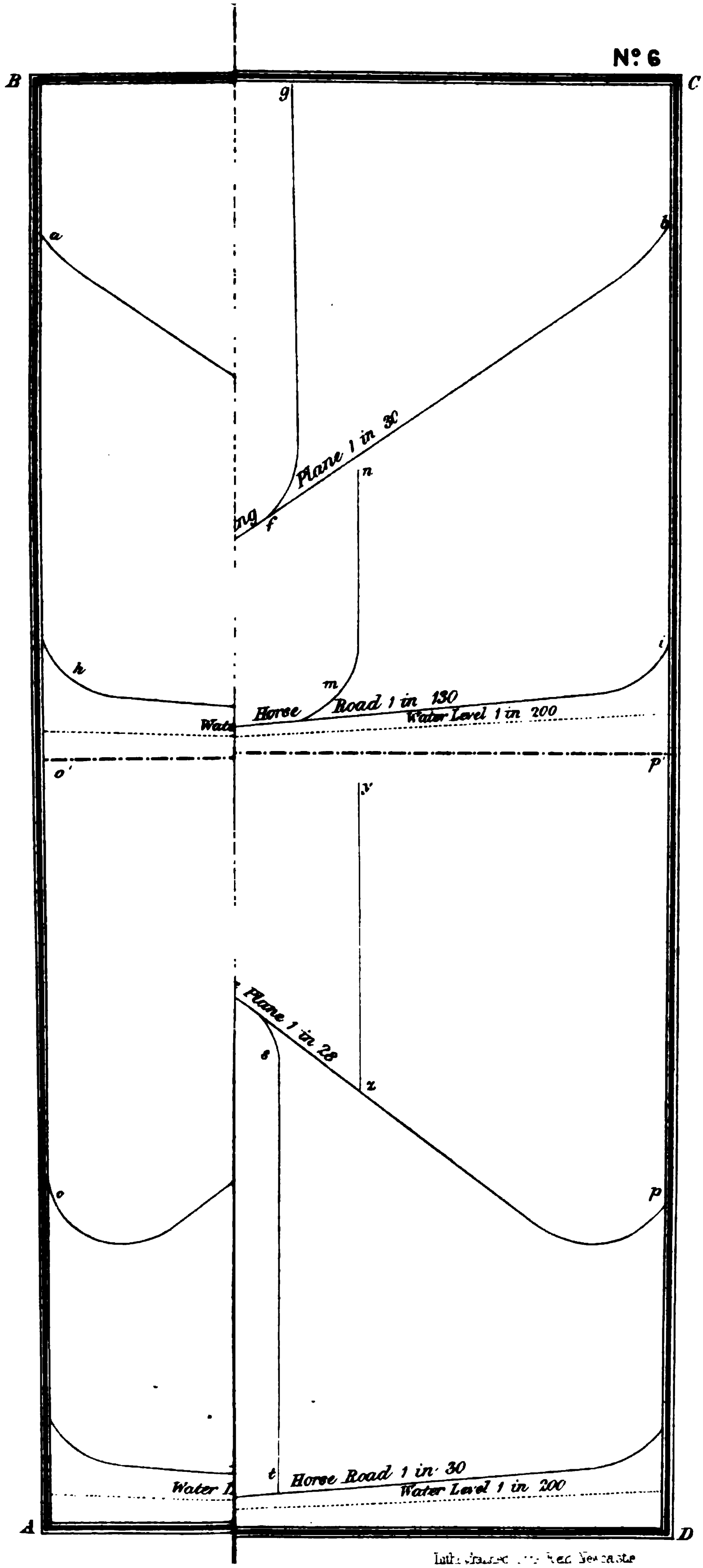
It is at all times a subject of vital importance to the trade to economise as much as practicable the conveyance of coal from the workings to the bottom of the shaft, the more so as coal at much greater depths from the surface, and also much greater distances from the shafts, being now worked, and the pits being more expensive to sink, they are consequently much further apart. Two papers on the subject, by Mr. N. Wood, were read to the Institute of Mining Engineers, Vols. VI. and VIII., in which the whole system of conveyance was investigated.

The annexed diagram is laid down as representing the whole system of underground conveyance, and by which plan steam engine power, or gravity as self-acting, could be exclusively employed, except in occasional cases where horses were used as auxiliary to those mechanical powers.

The diagram shows the manner a coal-field, of considerable extent, may be laid out so that coals may be conveyed from the stations to the bottom of the shaft, almost exclusively by steam engine power, or by self-acting planes, and without having recourse to horse-power. Steam engine planes, above two miles in length, are at present in use; hence the diagram would represent a coal-field of four square miles or 2560 acres in extent.

It will be seen, likewise, that almost if not more, than one-half of the Northumberland and Durham coal-field is covered by the sea. The

No. 6



Lith. ... Newcastle

line of section from Warkworth to South Wingate, No. 4, shows that all along that line the coal lies at a considerable depth from the surface, and that such line passes to the west of the point of lowest depression above the high water mark; and also that, for a considerable distance along that line, even at the point of depression at Monkwearmouth, the beds of coal dip towards the sea, showing that the point and line of lowest depression is to the east or seaward. With reference, therefore, to the conveyance of the coal which lies underneath the sea, it becomes a subject of the greatest importance, both in a practical and economical point of view, how that can be accomplished.

We have instances of engine planes at present in use $2\frac{1}{4}$ to $2\frac{1}{2}$ miles in length. There seem to be no engineering difficulties in extending that distance. The papers alluded to above show, by experimental deductions, that steam can be conveyed considerable distances, if properly arranged, and without loss of power; and, therefore, that engines may be placed at great distances from the shaft. We have also the case of the underground railway, showing that locomotive power may be used without the production of smoke or heat, which would be objectionable in underground lines of railway, and we have already had an attempt to introduce a locomotive engine into the workings of one of the collieries of Northumberland; we thereupon conclude that coals may be conveyed for very great distances indeed below the sea.

When the time arrives for the conveyance of coal for more extended distances than at present, we see no reason to doubt, from past experience, that means will be devised to accomplish that object.

It may likewise be mentioned that water is pumped from great distances underground, by the friction of the wire ropes, used in drawing the coals, passing round a sheave to the axle of which the pumping apparatus is attached. In one instance, a twenty-four-horse power engine draws 400 tons of coals per day, and lifts the water from the lowest level of a plane, 1300 yards long, 156 feet perpendicular, to the bottom of the shaft, and 270 feet to the surface, a total of 426 feet perpendicular.

Compressed air has also been successfully introduced in underground conveyances at considerable distances from the shafts, and seems likely to be very efficient for long distances. The steam engine compressing the air being either placed on the surface, or at the bottom of the upcast shafts, and the compressed air taken into the working stations by pipes, where the engines are worked to convey the coal.

No. 10.—THE EFFECTS OF THE INTRODUCTION OF RAILWAYS AND LOCOMOTIVES, SCREW STEAMERS, AND INLAND COMPETITION ON THE COMMERCIAL CHARACTER AND STATE OF THE NORTHERN COAL TRADE.

We have already stated, under the head of "Account of New Discoveries, and their Application connected with the Coal and Coke Trades," that one of these discoveries was the introduction of railways; next, that of locomotive engines, and then that of screw steamers. We have now to consider their several effects upon the Northern Coal Trade, including, in the consideration thereof, the inland competition promoted by the introduction of railways and powerful locomotive engines.

It is unnecessary for us, in this section of the paper, to enter into the history, or into the details of the introduction of those powerful and important elements of locomotion for the conveyance of coal. Separate sections, devoted to these details, have been undertaken by different gentlemen. We shall confine ourselves, therefore, in this paper, to the effects of the conveyance by such machines on the coal and coke trade.

For a long period of time, extending to a remote date, the country trade in coals was conducted by the conveyance of the coals on pack horses, mules and asses; the coals were placed in bags, and laid upon the backs of these animals; and, within the recollection of the present generation, vast numbers of these animals were used for such a purpose, along roads impassable by carts. When the roads were improved, and carts could be used, the usual load for a horse was about one ton, conveyed 10 miles a day. Wooden railways were first used about the year 1632, when the load conveyed was increased to two tons in one wagon, or four tons in two wagons on a favourable gradient. But the pits in the early period of coal mining being generally situated at or about the outcrop of the coal, or elevated parts of the district, two wagons were used; an extra horse being used in the more hilly parts of the road to drag up the empty wagons. After wooden rails only were used, a partnership on the Tyne employed above 350 horses in the conveyance of their coals from the pits to the river, from whence they were conveyed in barges or keels to the ships.

Cast iron rails were first used at the collieries in Durham and Northumberland about the year 1794, and malleable iron rails in 1815, first in the shape of tram roads, and, ultimately, as round topped rails. Before the introduction of locomotive engines, horses were the motive power

used, the usual load for a horse on the cast iron roads being ten to twelve tons on a level or slightly inclined road, and the distance conveyed 20 to 24 miles a day; 10 or 12 miles loaded, and 10 or 12 miles empty. Thus, the progressive improvements in the conveyance of coal was, on common roads, one ton conveyed 10 to 12 miles per day, with horses; on wooden railways, three to four tons, conveyed 10 to 12 miles per day, or 30 to 40 tons one mile per day; and when cast iron rails were adopted, 120 to 140 tons conveyed one mile per day.

Then came the introduction of locomotive engines. First on the Wylam Railway, on a tram road, in 1813, and then the improved locomotive, on the round topped rails, in 1814, by Mr. Stephenson. In the early period of the introduction of the locomotive, the assigned performance of a locomotive was 40 tons, conveyed six miles per hour; and on an enquiry respecting the performance of a locomotive at the period of the opening of the Liverpool Railway, in 1829, the performance assigned by Messrs. Walker and Rastrick was 33 tons, conveyed five miles per hour, and by Messrs. R. Stephenson and Locke 45 tons, conveyed at the rate of 12 miles an hour.

Since that period, malleable iron has been universally adopted in railways, and heavier rails have been laid down. On the Liverpool and Manchester Railway, the weight of the original rails was 35lbs. per yard, now rails of 84lbs per yard are universally used. The locomotive engines, which, as improved engines at the time of the Liverpool Railway opening, were stated by Stephenson and Locke to have an evaporating power of 13 cubic feet per hour, are now stated, in the accompanying paper on locomotive engines, to have an evaporating power of 144 cubic feet per hour, and the performance from 45 tons, conveyed at the rate of 12 miles per hour, has been increased to 300 tons, conveyed 20 miles per hour, or over an extent of line of 235 miles, from Darlington to London, in about 16 or 17 hours, including stops.

This performance has been accomplished on the narrow gauge of railway, of 4 feet 8½ inches. Upon the broad gauge of the Great Western Railway, which admits of more powerful engines being used, the evaporating power is much greater.

Whilst the motive power on railways was confined to horses and less powerful locomotives, the benefits derived by the coal trade from the improvements of railways, was local; confined to cheapening the conveyance of the coal from the pits to the shipping places for sea-sale, or to the depôts on the different local lines of coal for land-sale. But when the

railways and locomotives were improved, and the conveyance of coal was reduced to a comparatively small cost, then the public railway companies set up a competition with the Northumberland and Durham Coal Trade for the London and distant coastwise markets, the former sending coals by railway conveyance and the latter by sea.

Steam had been applied to the propulsion of ships in 1812, and it was suggested, especially after the introduction of the screw into steamboats, whether a description of vessel propelled by steam, could not be devised which would, by carrying a considerable quantity of coal, and using water as ballast in the return voyage, economise the conveyance of coal to the distant coasting ports and to London, to compete with the conveyance by the improved and powerful locomotive engines upon railways.

The competition as regards railways, of course, rests upon the quantity of coals conveyed by the present locomotive engines, and upon the cost of such conveyance.

And as regards screw steamers, the screw steamer "Killingworth," of 70-horse power, belonging to Mr. Nicholas Wood, made, in the year 1862—from Jauuary 10th, 1862, to January 9th, 1863—sixty-five voyages from West Hartlepool to London; loading at West Hartlepool, and delivering in the Victoria Dock, London, 38,738 tons 19 cwts. of coals, or an average of 596 tons per voyage.

Since the "Killingworth" was built, in January, 1855, a larger description of vessel, conveying 900 or 1000 tons at a time, has been introduced into the trade, and, requiring very little more power of engine, has been found to be more economical. And we may suppose that probably still more powerful engines may be used on the railways; so that the competition between the two modes of conveyance may be said to be very close, if the charges for each description of motive power rests upon the actual cost of each.

The practical effect upon the coal trade of the north by the introduction of railways and the conveyance of coal by locomotive engines has been that, in the year 1862, 1,531,421 tons of coals were sent to the London market, out of 4,973,823 tons consumed in that port.

From the "Statistical Abstract of the United Kingdom," 1848-62, it appears that the increase in the tonnage of screw steamers has been from 108,221 in 1849, to 461,792 in 1862.

No. 11.—THE DURATION OF THE COAL-FIELD.

It has been intimated that it would be very desirable that some observations should be made on the duration of the Northern Coal-field. No doubt the quantity of coal yet to work in that coal-field is a subject of national importance; but, from the observations already made, it will have appeared that such a calculation is attended with more than ordinary difficulty. The coal-field may be said to be that of an oval basin, elongated north and south. On the western side of the basin the outcrop of the seams is pretty well defined, but more than one-half of the basin appears to be covered by the sea, under which at present it may be said that no explorations have been made. On examining the line of section No. 4, viz., from Warkworth Colliery, at the northern extremity, to Castle Eden Colliery, near the southern extremity, the beds of coal lie at a very considerable depth below the water level of the sea, and that line of section passes through the deepest explored part of the coal-field, as will be seen by the observations made on section No. 4. The lowest known point of deepest depression being the Hutton-seam (below which there are several workable beds of coal) which seam, at Monkwearmouth Colliery, is 300 fathoms below the level of the sea.

We have stated that the line of the sea coast does not pass over the line of the deepest part of the basin, but that for a very considerable distance the beds of coal dip to the east, or underneath the sea. We do not know how far beyond the sea shore the beds continue to dip, or at what distance beyond the line of the coast the greatest depression of the coal beds will be found. Until further and more extensive explorations determine this, we are completely at fault as to the quantity of coal lying underneath the sea.

We see, therefore, the difficulties which we have to encounter in approaching such an enquiry, and we naturally ask, can such an enquiry at the present moment be of the least practical utility. We have not yet reached the threshold of such a conjecture. We have not yet explored one square mile of this vast unknown space, or determined one of the many elements required in such an intricate and uncertain investigation, and we have come to the conclusion that, to say the least, such an investigation can be of no practical utility, and that the attempt, at present, to fix the duration of the coal-field is at the least premature.

PRODUCE OF COAL IN NORTHUMBERLAND AND DURHAM.

1861.

	Tons.
House Coal	4,493,450
Gas Coal	1,717,000
Steam Coal, Small and Manufacturing Coal	4,317,120
Sent by the North-Eastern Railway to the Provinces passed on the Line	2,180,000
Distributed on the Carlisle Line	120,000
Coke consumed in Iron Trade	5,000,000
Alkali and other Manufactures	1,250,000
Colliery and Home Consumption	2,200,000
Duff and Waste	500,000
Total	21,777,570

APPENDICES.

No. 1.—COMPOSITION OF COAL.

We quite agree with Dr. Percy, that the ultimate composition of a coal throws little or no light on the purposes to which it can be most profitably applied; but such analysis, taken in conjunction with the results of other methods of examination, may be safely employed by the coalowner to guide him to the market most suitable for his coal.

We quote some analytical results of some of these methods, with samples characteristic of the different kinds of coals mentioned in the Report.

1.—Calorific Value.

The figures which follow, represent the number of lbs. of water which 1 lb of each coal could boil off from a temperature of 212° F.:—

Household Coal	13·72
Gas Coal	15·37
Steam Coal	14·85
Coking Coal	15·23

2.—Coke Assay.

The examination of the coal for this purpose, is made according to the method prescribed by the French authorities:—

		Household.	Gas.	Steam.	Coking.
Coke	Carbon	71·81	68·11	60·59	70·72
	Ashes	0·58	0·95	1·01	2·21
Gaseous products		27·61	30·94	38·40	27·07
		100·00	100·00	100·00	100·00

3.—Gas Analysis.

This method of analysis furnishes very reliable results as to the quality of a coal for the manufacture of gas, oil, &c.:—

		Household.	Gas.	Steam.	Coking.
Coke	Carbon	74·70	68·89	65·76	69·90
	Ashes	0·20	2·29		2·00
Tar		8·15	11·24	16·16	8·40
Gas water		1·30	1·34	0·50	1·25
Carbonic Acid		0·86	0·70	0·76	0·39
Sulphuretted Hydrogen		0·14	0·22	0·14	0·11
Gas		14·65	15·32	16·68	17·95
		100·00	100·00	100·00	100·00

4.—ULTIMATE ANALYSIS.

This method merely gives the ultimate elements which are contained in the coal, but furnishes no information how these elements are combined, nor what are really the proximate constituents of the coal :—

	Household.	Gas.	Steam.	Coking.
Carbon	83·47	82·42	82·24	81·41
Hydrogen	6·68	4·82	5·42	5·83
Nitrogen	1·42	11·97 (Nitrogen and Oxygen)	1·61	2·05
Oxygen	8·17		6·44	7·90
Sulphur	0·06	0·86	1·35	0·74
Ash	0·20	0·79	2·94	2·07
	100·00	100·86	100·00	100·00

CINDER COAL.

The peculiar action of a basaltic dyke in changing the composition of the coal in its immediate vicinity, has been shown by some analyses in an interesting paper by Messrs. Clapham and Daglish, from which we quote the following (taken from a paper contributed Mr. H. Taylor to the Institute of Mining Engineers, Vol. III.):—

	Haswell Hutton Seam.	Cinder Coal at Dyke.	Coal 68 yards from Dyke.
Carbon	84·284	80·255	89·916
Hydrogen	5·522	2·405	3·441
Nitrogen	2·075	1·170	2·129
Oxygen	6·223	0·923	1·228
Sulphur	1·181	1·646	1·267
Ash	0·715	13·601	2·019
	100·000	100·000	100·000

Or, deducting the ash, the results are as follow :—

Carbon	84·890	92·888	91·768
Hydrogen	5·561	2·783	3·511
Nitrogen	2·089	1·354	2·172
Oxygen	6·267	1·068	1·253
Sulphur	1·189	1·905	1·293

No. II.—GASES FOUND IN COAL MINES.

The recent melancholy loss of life in Hartley Colliery, has drawn some attention to the gases which are found in working the coal.

The following table contains all the analyses of these gases, which have been published :—

TABLE OF ANALYSES OF FIRE-DAMP.

COLLIERY OR PIT.	SEAM OR SOURCE OF GAS.	Spec. Grav. Observed.	Spec. Grav. Calculated.	Light Carburetted Hydrogen.	Air.	Nitrogen.	Oxygen.	Carbonic Acid.	Hydrogen.	Olefiant Gas.	AUTHORITY OR CHEMIST.
Wallsend	Bensham	60·24	59·91	91·00	9 00	...	...	...	...	...	Turner.
Ditto	Ditto	...	...	77·50	...	21·10	...	1·30	...	...	Playfair.
Ditto	Pipe above ground......	...	...	92·80	...	6·90	0·60	0·30	...	...	Do.
Hebburn	24 feet below Bensham	...	...	91·80	...	6·70	0·90	0·70	...	...	Do.
Ditto	Ditto (a month after)...	...	...	92·70	...	6·40	...	0·90	...	...	Do.
Ditto	Bensham	...	...	86·50	...	11·90	...	1·60	..	...	Do.
Ditto	Ditto	63·27	...	...	...	...	0·60	...	...	...	Graham.
Jarrow	Ditto	63·81	64·10	81·50	18·50	...	...	...	...	...	Turner.
Ditto	Ditto	...	...	83·10	...	14·20	0·40	2·10	...	...	Playfair.
Ditto	Five-quarter	...	...	93·40	...	4·90	...	1·70	...	...	Do.
Ditto	Low Main	...	...	79·70	...	12 13	3·00	...	3·00	...	Do.
Ditto	Ditto, 11 fathoms lower	62·09	60·79	89·00	11 00	...	...	...	...	...	Turner.
Burradon	Yard Coal	60·00	59·03	91·00	9·00	...	...	...	...	...	Do.
Killingworth......	High Main	61·96	62·36	85 00	8 00	7·00	...	...	...	...	Do.
Ditto	Low Main	82·26	83·25	37·00	46 50	16 50	1·00	...	...	...	Do.
Ditto	....	63·86	...	82·50	...	16·50	...	...	...	...	Graham.
Ditto	....	...	...	66·30	23 35	6·32	...	4·03	...	...	Richardson.
Hetton	Main, 100 fathoms......	78·00	77·24	50·00	23 00	27·00	...	...	...	...	Turner.
Ditto	Hutton, 175 do.	74·70	76·77	50·00	6·00	44·00	...	...	...	...	Do.
Pensher	Hutton, Waste, 125 do.	96·60	96·62	7·00	82 00	11·00	...	...	...	...	Do.
Townley	Three-quarter Seam ..	...	...	56·17	33·15	4·68	...	6·00	...	...	Richardson.
Well Gate	Five-quarter do......	...	...	98·20	...	1·30	...	0·50	...	...	Playfair.
Gateshead	Ditto do	58 02	...	94·20	...	4·50	1·30	...	...	...	Graham.
Cwm Turch	....	...	...	19·30	...	63·80	15·50	0·80	...	...	Playfair.
Wellesweiler	....	...	...	87·43	...	2·22	...	4·30	...	6 05	Bischof.
Gerhardt...........	....	...	...	79·84	...	14·36	...	3·90	...	1·90	Do.

Of the explosive gases, it may be observed that olefiant gas has, hitherto, only been found in the German mines, while light carburetted hydrogen alone, is met with in England, except in one solitary instance, where Playfair discovered hydrogen.

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The formation of these gases during the conversion of woody fibre into coal, is readily explained by means of the following formula :—

Thus, if we deduct from the elements of wood ...		...$C_{36}\ H_{22}\ O_{22}$
9eq. of carbonic acid	... C_9 — O_{18}	
8eq. of water	$H_8\ O_8$.	
Elements of splint coal ...	... $C_{24}\ H_{18}\ O$	$= C_{33}\ H_{16}\ O_{22}$
We obtain 3eq. of carburetted hydrogen ...		$C_3\ H_6$
Deducting from the elements of wood		$C_{36}\ H_{22}\ O_{22}$
10eq. of carbonic acid ...	... C_{10} — O_{20}	
1eq. of water	$H\ O$	
The elements of Boghead Coal	... $C_{18}\ H_{13}\ O$	$= C_{28}\ H_{14}\ O_{22}$
There remains 4eq. of olefiant gas		$C_8'\ H_8$

The gas which caused the death of the unfortunate men at Hartley, was carbonic oxide, which had most probably been produced by the imperfect combustion of the fuel in the furnace.

The poisonous properties of this gas were first pointed out by Clement and Desormes, in 1802, which were afterwards confirmed by Sir H. Davy and Nysten; and in 1814 two assistants of Mr. Higgins, who made some experiments with it upon themselves, nearly lost their lives. The most careful experiments on this subject, were made by Tourdes and Leblanc, who have proved that the fatal effects of choke-damp are chiefly due to the presence of this gas, which is formed by the imperfect combustion of the light carburetted hydrogen. Bernard has shown that the mode in which it proves so fatal, arises from the facility with which it combines with the blood and displaces the oxygen; and so complete is this action, that the French physiologist recommends its use in estimating the quantity of oxygen in the blood.

Numerous fatal cases are on record, proving the poisonous character of this gas; among which may be mentioned the accident at Strasburg, where water-gas was used for illuminating that city, and the loss of life in a lead mine in Cumberland.

It has never been detected as a natural product in coal mines; but the peculiarities of the accident at Felling Colliery, in 1845, would seem to indicate its presence on that occasion; and we have been informed that the so-called "white stythe," sometimes found in the Midland Collieries, is supposed to be carbonic oxide.

The following experiments were made by Messrs. Richardson, Browell, and Marreco to ascertain the effect of different mixtures of atmospheric air and carbonic oxide, on the flame of a candle:—

Per centage of Carbonic Oxide in the Mixture.	Observations.
2·5......	No visible effect.
5·0......	Ditto.
10·0......	Ditto.
12·5......	Flame apparently elongated, but very slightly.

Per centage of Carbonic Oxide in the Mixture.

15·0......A large top on the flame, with the characteristic appearance of carbonic oxide.

20·0......The top much increased, but the candle burnt tolerably well.

23·0......Appearance same as last, and candle still burnt.

25·0......The candle extinguished, the mixture inflamed, and a disk of flame passed slowly to the bottom of the vessel.

28·5......The candle extinguished, and the gas burnt with a flash. This is the theoretical mixture for perfect combustion.

50·0, 70·0 ...These mixtures inflamed and burnt more or less rapidly.

Leblanc, and more recently Dr. Letheby, have proved that a mixture with one per cent. of this gas, is fatal to animal life; so that the old dictum, *where flame burns, life is safe*, does not hold good when this gas is present.

No. III.—MINERAL AND BRINE SPRINGS.

The discovery of the bed of rock salt at Middlesbrough lends additional interest to all the saline springs met with in the collieries of this district.

Many of these mineral waters, doubtless, owe their distinctive character to peculiar circumstances within a very limited area, such as the baryta waters of Walker and Harton, but, on the other hand, the brine springs at St. Lawrence and Birtley, may be derived from a source common to the whole of the coal formation.

As an illustration of the former class, we may quote the following analysis of a water which was met with at Wingate Grange, which had evidently been formed by the oxidation of a deposit of iron pyrites.

Sulphate of Iron	9·69
Sulphate of Alumina	0·91
Sulphate of Lime	5·10
Sulphuric Acid	4·43
Chloride of Sodium	trace
Chloride of Magnesium	trace
Organic Matter	trace
Solid matter per imperial gallon	20·13 grs.

The brine spring at St. Lawrence Colliery, contained (according to Dr. Richardson) in the gallon, as follows:—

Chloride of Sodium	2938·24
Chloride of Calcium	854·08
Chloride of Magnesium	193·92
Sulphate of Lime	44·88
Sulphate of iron	7·28
	4038·40 grs.

A somewhat similar water was found in Wallsend Colliery, but the constituents of this spring varied in a most extraordinary manner, as the following analyses (by Dr. Richardson) will show, one having been made in 1842, and the other in 1848.

	1842.	1848.
Chloride of Sodium...	trace ...	4550·49
Chloride of Calcium	7400·91 ...	2024·29
Chloride of Magnesium	trace ...	trace
Chloride of Aluminium	trace ...	......
Chloride of Iron	....	trace

These analyses naturally suggest many ideas as to the probable origin of the different constituents, but on the present occasion, it will be more consistent with the object of the report, simply to place them on record.

No. IV.—MINERALS FOUND IN THE COAL-MEASURES.

The most widely diffused of these minerals is known, in this district, under the name of *coal brasses*, the important constituent of which is *bi-sulphide of iron* or *iron pyrites*.

1.—Iron Pyrites.

This pyrites exists in larger or smaller masses, more or less mixed with coal and shale, from which it is removed by hand picking. In this comparatively purified form, it contains from 30 to 35 per cent. sulphur, and is now frequently used, along with foreign sulphur ores, for the manufacture of sulphuric acid.

The quantity of coal, however, which still remains disseminated through portions of the brasses, is a serious drawback to such an application. This coal can be removed by grinding the brasses to powder and then washing, a process which has been used by various parties, in this locality. The Jarrow Chemical Company adopted, in 1853, the plan of Dr. Richardson for this purpose, and obtained a tolerably pure pyrites, containing from 45 to 48 per cent. of sulphur. This purified material was made up into bricks with a small quantity of clay, which were dried and then burnt in the usual way for making sulphuric acid.

The residue presented the appearance of calcined black-band ironstone, and was, in fact, a very pure iron ore. Dr. Richardson, in 1855, induced a firm in the iron trade to employ this material in their blast furnaces, and the following is an extract from a letter of their able manager, in which he describes the result of a trial of many tons, during a period of several weeks:—"The proportion never exceeded one-fifth of burnt pyrites to four-fifths of calcined ironstone, being the same proportion, as we then used of Lancashire hematite ore, and, in fact, the calcined pyrites took the place of the hematite, as long as the supply lasted. The yield from the pyrites, as far as I could judge, was quite equal to that from the hematite ore, and we could see no apparent change in the working of the furnace, or in the quality of the iron, which was always as good as any in the district. I do not now remember what quantity of pyrites was used altogether, but I know we never had one complaint of our iron during the time it was being used up."

A sample of cleaned coal pyrites from Walker Colliery, analysed by Mr. Clapham, contained :—

Sulphur	40·50
Iron, as Oxide	46·35
Coaly Matter	7·90
Silica	1·55
Carbonate of Lime	4·00
	100·30

2.—Copper Pyrites.

This mineral is more generally diffused than might have been expected. Dr. Percy states that the anthracite of South Wales, used in the laboratories of the School of Mines, contains decided traces of copper, and Mr. Clapham informs us that he has often found traces of the same metal in the coal brasses of this district. Messrs. Richardson, Bunning, and Tomlinson, have also found it in the steam coal of South Wales.

Messrs. Clapham and Daglish have analysed a specimen from the middle of the Hutton Coal Seam at Seaton Colliery, found at a depth of 1500 feet. Their analysis is as follows:—

Copper	33·2
Iron	28·2
Sulphur	37·0
Carbon, &c.	1·6
	100·0

3.—Galena.

This mineral is of more frequent occurrence than copper pyrites, and we avail ourselves of the interesting paper of Messrs. Clapham and Daglish, to give the following information.

They analysed a specimen taken from a vein in the Hutton-seam, at Seaton Colliery, and found:—

Lead	52·48
Sulphur	11·40
Iron	2·10
Coal, &c.	34·02
	100·00

These gentlemen state that the coal in the vicinity of these veins is quite unchanged, which tends to show that the deposition of the galena was from solution, rather than by the action of heat.

They also mention that lead ore has been worked, to a small extent, in the Magnesian-limestone, near Castle Eden, above the Coal-measures, by a drift from the beach.

4.—Arsenic and Antimony.

Daubrée has found traces of both arsenic and antimony in the coal of this district. The former has been found by Dr. Richardson, in some quantity, in the sulphuric acid made exclusively from the coal brasses of this locality.

Messrs. Clapham and Daglish found from 0·1 to 0·3 per cent. of arsenic in some of the coal brasses they examined.

5.—Sulphuret of Nickel.

Messrs. Clapham and Daglish exhibited at the Chemical Section, a specimen containing beautiful crystals of sulphuret of nickel, embedded in carbonate of iron, which had been found in the South Wales Coal-field.

6.—Sulphate of Baryta.

This substance was first noticed by Dr. Richardson in a deposit from a feeder in the shaft of Walker Colliery. He found it to be composed of :—

Sulphate of Baryta	90·01
Sulphate of Lime	3·04
Peroxide of Iron...	0·30
Silica	2·65
Water	3·51
	99·51

It has since been discovered in Harton Colliery, and a large mass has also been found by Mr. G. B. Forster, in Felling Colliery. It also occurs in isolated nodules in the lower beds of the Magnesian-limestone.

7.—Phosphate of Lime.

The same gentlemen mention that this substance has been found in the form of a *coprolite*, in the bituminous shale, lying immediately over the Low Main-seam at Newsham Colliery, near Blyth, and that it contained 80 per cent. of phosphate of lime. This bed has received the name of the *fish bed*, from the numerous remains of fishes found in it.

8.—Mineral Wax or Grease.

This substance is occasionally found, and is called by the miners "bitumen," but it presents the general appearance of Hatchetine. It melts below 212° F., and is volatile at a higher temperature.

A specimen was found some years ago in the Urpeth Pit, and Messrs. Clapham and Daglish inform us that it was afterwards found in the Seaton Pit. They also state that, more recently, a quantity was found in the South Hetton Pit, where the pit boys used it for greasing the axles of their trams.

A specimen from one of the pits near Shotley Bridge, was analysed by Dr. Richardson, who found it to consist of :—

Carbon	85·49
Hydrogen	14·51
	100·00

Pit Shafts.

The lining of pit-shafts has attracted great attention, and the materials employed, justify us to some extent, in introducing the subject in this place. In doing so, we are glad to avail ourselves of the information and analyses contained in the valuable paper of Messrs. Clapham and Daglish, to which such frequent reference has been made.

The material generally employed is the sandstone of the district, containing

variable quantities of iron, lime, and magnesia, which being attacked by the sulphurous vapours from the ventilating furnaces and engine fires, gradually causes a disintegration and destruction of the sandstone.

This serious loss has been remedied by the adoption of lumps made of fire-clay, which resist the action of the vapours.

The same cause leads to the destruction of the metal tubbing, employed in so many shafts, and Messrs. Clapham and Daglish have examined specimens of these tubbings taken from Hetton and other collieries. They give the following analyses of some of these specimens:—

	1	2	3
Iron	72·00	3·00	59·20
Sulphur	3·00	1·42	3·28
Carbon	3·85	55·35	22·72
Silica	0·65	34·15	......
Water	16·00	6·20	14·72
	95·50	100·12	99·92

No. V.—SYNOPSIS OF ORGANIC REMAINS FOUND IN THE NORTHUMBRIAN COAL-MEASURES.—By Richard Howse.

The Carboniferous rocks properly include the Devonian, Carboniferous, and Permian groups which conjointly form the Upper-palæozic division of the sedimentary deposits.

Palæozic Rocks.

Upper.	Permian group. Carboniferous group. Devonian group.	Chief deposits of coal.
Lower.	Upper Silurian group. Lower Silurian group. Cambrian group.	Traces of coal.

In the Devonian group, many of the plants of the Carboniferous period for the first time appear, and the Permian is linked on to the Carboniferous by many indissoluble ties. Some of these relationships are shown in the following Synopsis, but it requires a more comprehensive list to express the whole of them.

Only the most generally recognized species are admitted into the present list, and of these probably many are merely synonyms; but as much time and labour would be required to examine them critically, and as their admission does not affect their comparative distribution, it has been thought advisable to include them under their generally known names. Future researches will no doubt considerably increase the number of true species.

About 2400 species of plants have been found in the sedimentary deposits of the earth's crust. Of these rather more than one-third are peculiar to the Car-

boniferous rocks, and about one-eighth of them have been found in the coal-fields of Great Britain. In this coal-field, notwithstanding the great number of specimens that have been collected and examined, only about 130 species have been recorded. These have been collected chiefly from the shales covering the three most important coal-seams of the Tyne district, viz.:—The High-Main, Bensham, and Low-Main. Very few fossil plants from the lower coal-seams, or from the Millstone-grit and Mountain-limestone series, have been collected or recorded, although their remains are very generally distributed through many of the beds of both these series. The species included in this list are generally supposed to belong to the following classes, viz.:—

Filices, *Ferns*	49
Calamariæ, *Mare's tails*	19
Selagineæ, *Club mosses*	46
Coniferæ, *Fir tribe*	7
Plantæ incertæ sedis, *of doubtful affinity*	11
	132

It will be seen at a glance that, with the exception of a few Coniferæ, these all belong to the highest forms of cryptogamic plants. Excepting a few traces of *Fungi*, none of the more humble forms of vegetation have been recognized in this district, and only a few, comparatively, in other parts of the world. But may we not expect that future and more careful researches, and other methods of discovery, will reveal to us the at present concealed remains of the more lowly tribes of the cryptogamiæ, whose readily decomposing forms may have had considerable influence in forming many of the various beds of coal? At least it seems safe to infer, that where so many gigantic and extraordinary forms of the higher cryptogamic plants grew and revelled, their more lowly brethren would not be entirely absent, and if they were present, their discovery is a desideratum greatly to be desired.

The animal remains hitherto detected in this district consist of a few species of freshwater Mollusca, *Unionidæ*, and one marine shell, *Lingula mytiloïdes;* Annulose animals, *Entomostraca;* and the burrows of Crustaceans or of Insecta, have also been observed, though the remains of the agents themselves have not yet come to light. Numerous remains of large sauroidal fishes also occur. Those quoted in this list have been collected chiefly by Mr. Atthey, from the neighbourhood of Cramlington and Seaton Delaval, out of a bed of black shale resting on the Low Main-seam. Most of these have been identified by Mr. Kirkby and Mr. Atthey.

The plants from the lower seams are on the authority of Mr. J. B. Simpson of Ryton, and those from the Mountain-limestone group, on the authority of Mr. Geo. Tate, of Alnwick.

It is the intention of Messrs. R. Howse and J. Taylor to investigate hereafter the comparison of the fossils of the English and Foreign Coal-formations with the Northumbrian coal-field, in a more complete manner.

The references in the following table are to the plates in Lindley and Hutton's Fossil Flora.

TABLE SHOWING THE BATHYMETRICAL DISTRIBUTION OF ORGANIC REMAINS IN THE NORTHUMBRIAN COAL-MEASURES, AND THEIR GEOGRAPHICAL RANGE.

No. of Species in each Class	CLASSES, GENERA, AND SPECIES.	Bathymetrical Distribution. Permian Group.	Bathymetrical Distribution. Carboniferous Group. Coal Measure Series. Highest* Beds.	Bathymetrical Distribution. Carboniferous Group. Coal Measure Series. High Main.	Bathymetrical Distribution. Carboniferous Group. Coal Measure Series. Bensham.	Bathymetrical Distribution. Carboniferous Group. Coal Measure Series. Low Main	Bathymetrical Distribution. Carboniferous Group. Coal Measure Series. Lowest Seams.	Bathymetrical Distribution. Carboniferous Group. Millstone Grit Series.	Bathymetrical Distribution. Carboniferous Group. Yoredale Series.	Bathymetrical Distribution. Carboniferous Group. Scar Limestone Series.	Bathymetrical Distribution. Carboniferous Group. Tuedian Series.	Bathymetrical Distribution. Devonian Group.	Geographical Distribution. Coal Measures. England.	Geographical Distribution. Coal Measures. Germany and France.	Geographical Distribution. Coal Measures. America.	Geographical Distribution. Devonian or Old Red Group.
	PLANTÆ.															
	Filices.															
1	Adiantites concinnus, t. 115	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
2	obovatus, t. 109	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...
3	Alethopteris heterophylla, t. 38	...	...	x	...	...	...	...	...	...	...	...	x	...	...	...
4	lonchitidis, t. 153	...	...	...	...	x	...	...	...	...	...	...	x	...	x	...
5	Mantelli, t. 145	...	...	...	...	?	...	...	...	...	...	...	x	...	...	...
6	? Aphlebia adnascens, t. 100, 101	...	...	...	...	x	...	...	...	...	...	...	x	x	...	...
7	? Cyclopteris dilatata, t. 91	...	x	...	...	x	...	...	...	...	...	...	...	...	x	...
8	Hymenophyllites dissecta, *Sternb*	...	...	..	...	...	...	...	...	...	...	...	x	x	...	...
	furcata, t. 181	...	...	...	x	...	...	...	...	...	...	...	x	x	?	...
9	? Megaphytum approximatum, t. 116	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...
10	distans, t. 117	...	...	...	...	x	...	...	...	...	...	...	x	...	...	...
11	Neuropteris acuminata, t. 51	...	...	...	...	x	...	...	...	...	...	...	...	x	...	...
12	attenuata, t. 174	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...
13	auriculata, *Brong.*	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
14	gigantea, t. 52	...	x	...	x	x	...	...	...	...	...	...	x	x	x	...
15	Grangeri, *Brong.*	...	...	...	...	...	...	...	...	...	...	...	x	...	x	...
16	heterophylla, t. 183	...	...	x	...	...	...	...	...	...	...	...	x	x	x	...
17	Lindleyana, t. 49	...	...	...	...	x	...	...	...	...	...	...	x	x	x	...
18	Loshii, *Brong.*	...	...	...	...	x	...	...	...	...	...	...	x	x	x	x
19	rotundifolia, *Brong.*	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...
20	Soretii, *Brong.*	...	...	...	...	x	...	...	...	...	...	...	x	...	...	...
21	tenuifolia, *Sternb.*	...	x	...	...	x	...	...	...	...	...	...	x	x	x	...
22	Thymifolia, t. 50	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
23	Odontoperis Britannica, *Sternb.*	...	?x	...	...	x	...	...	..	...	...	...	x	x	...	...
24	Pecopteris adiantoides, t. 37	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
25	Brongniartiana, t. 54	...	...	...	...	...	?	...	..	...	...	...	...	...	...	...
26	caudata, t. 138	...	...	...	x	...	...	...	...	...	...	...	...	x	...	...
27	laciniata, ? t. 122	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
28	Loshii, *Brong.*	...	...	...	?	...	...	...	...	...	...	...	...	...	x	...
29	marginata, t. 218	...	...	...	?	...	...	...	...	...	...	...	...	...	?	...
30	Miltoni, *Brong.*	...	...	x	...	...	...	...	...	...	...	...	x	x	...	...
31	muricata, t. 122	...	...	...	x	...	...	...	...	...	...	..	x	x	x	...
32	nervosa, *Brong.*	...	x	...	x	...	x	...	...	...	...	...	x	...	x	...
33	repanda, t. 84	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
34	Sphenopteris adiantoides, t. 115	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
35	affinis, t. 45, 46	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
36	artemisiaefolia, *St.*	...	...	...	...	x	...	...	...	...	...	...	x	...	x	...

* This division includes the English Lower-new-red-sandstone, and the German Rothliegendes, neither of which can be consistently separated from the true Coal-Measures.

TABLE OF THE DISTRIBUTION OF ORGANIC REMAINS (CONTINUED).

		Bathymetrical Distribution.											Geographical Distribution.			
			Carboniferous Group.										Coal Measures.			
			Coal Measure Series.													
No. of Species in each Class.	Classes, Genera, and Species.	Permian Group.	Highest* Beds.	High Main.	Bensham.	Low Main.	Lowest Seams.	Millstone Grit Series.	Yoredale Series.	Scar Limestone Series.	Tuedian Series.	Devonian Group.	England.	Germany and France.	America.	Devonian or Old Red Group.
37	Sphenopteris Brongniartii, *Sternb*	...	...	...	...	x	...	...	...	...	...	...	x	...	...	...
38	caudata, t. 48, 138	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...
39	crenata, t. 100, 101	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
40	cuneolata, t. 214	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
41	excelsa, t. 212	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
42	gracilis, *Brong.*	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
43	Hœninghausi, t. 204	...	...	...	...	x	...	...	...	...	...	...	x	x	...	...
44	latifolia, t. 156, 178	...	x	x	...	x	x	...	...	...	...	...	x	x	x	...
45	laxa, *Sternb.*	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
46	linearis, t. 230	...	...	...	...	x	...	...	...	...	...	...	x	x	..	...
47	macilenta, t. 151	...	...	...	...	x	...	...	...	...	...	...	x	x	...	...
48	obovata, t. 109	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
49	stricta, *Sternb.*	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
	CALAMARIÆ.															
1	Calamites ? approximatus, t. 216	...	x	x	x	x	...	...	...	...	...	...	x	x	x	...
2	cannaeformis, t. 79	...	...	...	x	...	x	...	...	x	x	...	x	x	x	x
3	inaequalis, t. 196 ?	...	x	...	...	...	...	...	...	...	...	...	x	x	...	...
4	nodosus, *Schloth.*	...	...	...	?x	...	...	...	...	...	...	...	x	x	x	...
5	ramosus, t. 15, f. 1	?	x	...	...	x	...	...	...	...	...	...	x	x	x	...
6	Steinhaueri, *Brong.*	...	x	...	...	...	...	...	...	...	...	...	x	x	x	...
7	Suckowii, *Brong.*	...	x	...	...	...	...	...	...	x	...	...	x	x	x	...
8	Asterophyllites, ? dubia, t. 19	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
9	foliosa, t. 25, f. 1	...	...	...	x	...	...	...	...	...	...	...	x	...	x	...
10	grandis, t. 19, f. 2	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
11	jubata, t. 133	...	...	...	x	...	...	...	..	...	...	...	x	...	...	...
12	longifolia, t. 18	...	...	...	x	...	...	...	...	...	...	...	x	x	x	...
13	rigida, t. 211	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
14	tenuifolia	...	...	...	?x	...	...	...	...	...	...	...	x	...	...	...
15	? tuberculata, t. 14	...	...	...	x	x	...	...	...	...	...	...	x	x	x	...
16	Hippurites gigantea, t. 114	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
17	*longifolia*, t. 190, 191	...	...	..	?	...	...	...	...	...	...	...	x	...	...	...
18	Sphenophyllum dentatum, *Brong*	...	...	...	x	...	...	...	...	...	...	...	x	x	...	...
19	erosum, t. 18	...	...	...	x	x	...	...	...	...	...	...	x	...	x	...
	SELAGINES.															
1	Aspidiaria quadrangularis, *Presl*	...	...	...	x	...	...	...	...	..	...	...	x	x	...	...
2	undulata, *Presl*	...	...	...	x	...	...	...	...	...	...	...	...	x	x	...
3	Favularia (Sig.) nodosa, p. 192	...	...	...	...	...	x	...	...	...	...	...	x	...	...	...
4	Halonia tortuosa, t. 85	...	x	...	...	...	...	...	...	...	...	...	x	...	...	...
5	regularis, t. 228	...	...	x	...	...	...	...	...	...	...	...	x	...	...	...
6	Knorria Sellonii, t. 97	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
7	taxina, t. 95	...	...	...	x	x	...	...	...	x	...	...	x	...	x	...
8	Lepidophyllum lanceolatum, t. 7, f. 34	...	x	...	...	x	...	...	...	...	...	...	...	...	x	...

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TABLE OF THE DISTRIBUTION OF ORGANIC REMAINS (Continued).

No. of Species in each Class.	Classes, Genera, and Species.	Bathymetrical Distribution. Permian Group.	Carboniferous Group. Coal Measure Series. Highest* Beds.	High Main.	Bensham.	Low Main.	Lowest Seams.	Millstone Grit Series	Yoredale Series.	Scar Limestone Series.	Tuedian Series.	Devonian Group.	Geographical Distribution. Coal Measures. England.	Germany and France.	America.	Devonian or Old Red Group.
9	Lepidostrobus pinaster, t. 198 ...	...	...	x	x	...	...	...	...	...	...	...	...	...	x	...
10	variabilis, t. 10, f. 3, t. 11 ...	...	x	x	x	...	...	...	...	...	...	...	x	...	x	...
11	Lepidodendron acerosum, t. 7, f. 1. 8, f. 1, 2 ...	...	...	...	...	x	...	...	...	...	...	...	x	...	...	...
12	dichotomum, *St.*	...	...	...	...	x	...	...	...	...	...	...	x	x	x	..
13	dilatatum, t. 7, f. 2	...	...	...	...	x	...	...	...	..	...	...	x	...	...	...
14	dubium, *Brong.*	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
15	elegans, t. 118, 199	...	...	...	...	x	...	...	...	...	...	...	x	x	x	...
16	gracile, t. 9 ...	...	...	...	...	x	...	...	...	x	...	...	x	...	x	...
17	Harcourtii, t. 98	...	...	...	...	...	...	...	x	...	...	...	x	...	...	...
18	longifolium, t. 161	...	...	...	...	x	...	...	...	...	...	...	x	x	...	...
19	oocephalum, t. 206	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...
20	plumarium, t. 207	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
21	selaginoides, t. 12, 113	...	...	...	...	x	x	...	...	x	...	...	x	x	x	...
22	Sternbergii, t. 4, 112, 203 ...	...	...	...	...	x	...	...	...	x	...	...	x	x	...	...
23	Lycopodites cordatus, *Sternb.* ...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
24	phlegmarioides, *Brong.*	...	...	...	...	x	...	...	...	...	...	...	x	x	...	...
25	Lomatophloyos crassicaule, t. 225	...	x	x	x	x	...	...	...	...	...	...	x	x	x	...
26	Sagenaria Lindleyana, t. 19 *Sternb*	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...
27	ophiura, *Brong.* ...	...	...	...	...	x	...	...	...	...	...	...	...	x	...	...
?28	Sigillaria affinis	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
29	alternans, t. 56 ...	...	...	...	...	x	x	...	...	...	...	...	...	...	x	...
30	catenulata, t. 58 ...	...	...	...	...	x	...	...	...	...	...	...	...	...	x	...
31	elegans, *Brong.* ...	...	...	x	...	x	...	...	...	...	...	...	...	x	x	...
32	flexuosa, t. 205 ...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...
33	leioderma, *Brong.* ...	...	...	...	...	x	...	...	...	...	...	...	...	...	x	...
34	laevigata, *Brong.* ...	...	...	...	...	x	...	...	...	...	...	...	...	x	x	...
35	oculata, t. 59	...	...	...	...	x	x	...	...	...	...	...	x	x	x	...
36	organum, t. 70 ...	...	...	...	...	x	...	...	...	x	...	...	x	x	x	...
37	pyriformis, *Brong.* ...	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...
38	reniformis, t. 57, 71 ...	...	x	x	x	x	x	...	...	...	...	...	x	x	x	...
39	scutellata, t. 54 ...	...	...	...	...	x	...	...	...	...	...	...	...	x	x	...
40	tessellata, t. 73–75 ...	...	...	...	...	x	...	...	...	...	...	...	x	x	x	...
41	Stigmaria ficoides, *Auct.* ...	...	...	x	x	x	x	...	...	x	x	...	x	x	x	...
42	?Ulodendron Lindleyanum, t. 80, 81	...	...	...	...	x	...	...	...	...	...	...	x	?	x	...
43	majus, t. 5	...	...	...	...	x	...	...	...	...	...	...	x	x	x	...
44	minus, t. 6	...	...	x	...	x	...	...	...	x	...	...	x	x	x	...
45	Walchia piniformis	...	...	x	...	...	...	...	...	...	...	...	x	x	...	...
46	sp. indet	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...

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TABLE OF THE DISTRIBUTION OF ORGANIC REMAINS (CONTINUED).

No. of Species in each Class.	CLASSES, GENERA, AND SPECIES.	Bathymetrical Distribution. Permian Group.	Carboniferous Group. Coal Measures Series. Highest* Beds.	High Main.	Bensham.	Low Main.	Lowest Seams.	Millstone Grit Series	Yoredale Series.	Scar Limestone Series	Tuedian Series.	Devonian Group.	Geographical Distribution. Coal Measures. England.	Germany and France.	America.	Devonian or Old Red Group.
	CONIFERÆ.															
1	Dadoxylon? approximatum, t. 224	..	x	..	..	..	x	..	..	..	..	..	x	x	x	..
2	Brandlingi, t. 1 ...	..	x	..	..	..	..	..	..	..	..	..	..	x	..	..
3	Diploxylon elegans, *Cord.* ...	..	x	x	x	..	..	..	..	..	..	..	x	x	..	..
4	Noeggerathia flabellata, t. 28, 29	..	..	..	x	..	..	..	..	..	..	..	..	..	x	..
5	Picea Withami, t. 23, 24 ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
6	Pinites ambiguus, *Witham* ...	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
7	anthracina, t. 164 ...	..	..	..	..	?x	..	..	..	..	..	..	..	..	..	..
	PLANTÆ INCERTÆ SEDIS.															
	Flores.															
1	Antholithes Pitcairnia, t. 82 ...	..	..	..	x	x	..	..	..	..	..	..	x	..	..	..
	Folia.															
2	Cordaites Borassifolia, *Sternb* ...	..	x	x	x	x	..	..	..	..	..	..	x	x	x	x
	Fructus et semina.															
3	Cardiocarpon acutum, t. 76 ...	..	..	x	x	x	..	..	..	..	..	..	x	x	..	..
4	apiculatum ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
5	Carpolithes alatus, t. 87, t. 210 B	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
6	marginatus	..	x	..	..	..	..	..	..	..	..	..	x	..	..	..
7	Rhabdocarpus amygdalaeformis	..	..	..	..	x	..	..	..	..	..	..	..	..	x	..
8	Trigonocarpon Noeggerathi, t. 142, C.	..	x	x	x	x	..	..	..	..	..	..	x	x	x	..
	t. 193, f. 1-4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	t. 222, f. 2-4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Caules et radices.															
9	Pinnularia capillacea, t. 111 ...	..	x	..	..	..	x	..	..	..	..	..	x	x	x	..
10	Myriophyllites dubius	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
11	gracilis, t. 110 ...	..	..	..	..	x	..	..	..	..	..	..	x	..	..	..
	ANIMALIA.															
	MOLLUSCA															
	LAMELLIBRANCHIATA.															
	Unionidæ.															
1	Anthracosia acuta	..	x	..	..	..	x	..	..	..	..	..	..	..	..	..
2	„ spec. indet	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3	Anthracomya, spec. indet ...	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..
	BRACHIOPODA.															
4	Lingula mytiloïdes, *Sow* ...	x	..	x	..	..	..	..	..	x	..	..	x	..	?	..

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TABLE OF THE DISTRIBUTION OF ORGANIC REMAINS (CONCLUDED).

No. of species in each Class.	CLASSES, GENERA, AND SPECIES.	BATHYMETRICAL DISTRIBUTION.											GEOGRAPHICAL DISTRIBUTION.			
			CARBONIFEROUS GROUP.													
			COAL MEASURE SERIES.										COAL MEASURES.			
		Permian Group.	Highest* Beds.	High Main.	Bensham.	Low Main.	Lowest Seams.	Millstone Grit Series.	Yoredale Series.	Scar Limestone Series.	Tuedian Series.	Devonian Group.	England.	Germany and France.	America.	Devonian or Old Red Group.
	ANNULOSA.															
	Crustacea.															
1	**Beyrichia arcuata, *Bean*** ...	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..
2	**Leperditia Scotoburgdigalensis, *Hibb***	..	..	x	..	x	..	..	..	x	..	..	x	..	..	..
3	**Cythere, N. S.**	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..
4	**? Estheria, spec. indet**	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..
5	**? Microconchus carbonarius, *Murch***	..	x	x	x	x	..	x	..	x	..	..	x	x	..	..
	PISCES.															
1	**Gyracanthus tuberculatus, Ag.** ...	..	x	..	..	x	..	..	..	..	..	..	x	..	..	..
2	**formosus, Ag.** ...	..	..	..	..	x	..	x	..	..	..	..	x	..	..	..
3	**spec. indet**	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
4	**Pleuracanthus** „	..	..	..	..	x	.	..	..	..	..	..	..	..	..	..
5	**Orthacanthus** „	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
6	**Leptacanthus** „	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
7	**Ctenoptychius pectinatus, Ag.** ...	..	..	..	..	x	..	..	..	..	..	..	x	..	..	..
8	**spec. indet** ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
9	**Psammodus** „ ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
10	**Ceratodus** „ ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
11	**Ctenodus** „ ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
12	**Diplodus gibbosus, Ag.**	..	..	..	..	x	..	..	..	..	..	..	x	..	..	..
13	**Coelacanthus, spec. indet** ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
14	**Megalichthys Hibberti, Ag.** ...	..	..	x	..	x	x	..	..	..	..	..	x	..	..	..
15	**Holoptychius, spec. indet** ...	..	..	..	x	x	..	..	..	..	..	..	..	..	..	..
16	**Rhizodus** „ ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
17	**Platysomus, spec. indet** ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
18	**Palaeoniscus** „ ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..
19	**Amblypterus** „ ...	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..

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No. VI.—BORING.

The old system of boring, in which, up to a very recent period, scarcely any improvement has been effected, may now be said to be superseded by the very efficient apparatus of Messrs. Mather and Platt, Salford Iron Works, Manchester.

An excellent description of this boring machine is given in a paper on the Cleveland Rock Salt, by Mr. Marley, of Darlington.

The diameter of the bore-hole is eighteen inches, and the depth bored to the present time is 1306 feet.

The maximum rate in boring through the New-red-sandstone was 13 feet in thirteen hours, or one foot per hour.

When at a depth of 1100 feet a rate of three inches per hour was attained.

This very important improvement will undoubtedly be hereafter extensively adopted. The great advantages being, increased speed and accuracy, together with the further advantage of the stratum bored through being brought to the surface in pieces of three to four inches square; whereas under the old system, only very minute portions could be obtained.

No. VII.—COAL-CUTTING MACHINE.

Until within the last few years, no attempt had been made to work coal otherwise than by manual labour. Messrs. Donesthorpe and Co., of Leeds, and Mr. William Jenkins, of Cardiff, have, however, lately applied machinery to the working of coal. In the former case the motive power is produced by compressed air conveyed in pipes to the locality required; the engine being either on the surface or in the mine.

In the coal-cutting apparatus of Mr. Jenkins, the motive power is obtained by means of wire ropes attached to an engine.

This important question is only yet in its infancy, but so far as experiments have gone, there is every probability that it will succeed in all respects, more especially in the low seams of coal; which, owing to the great cost of manual labour, may at present be said to be practically unworkable.

We shall thus be enabled to work, profitably, seams of coal varying from one foot six inches to two feet in height, or even lower, and thus vastly prolong the duration of the coal-field. These seams having been excluded as unworkable in the calculations hitherto made of the duration of coal.

Another great advantage will be, that a much larger quantity of saleable round coal will be produced, the tendency of which is to cheapen the cost of working, and also, by preventing waste, to prolong the duration of the coal-field.

Messrs. Donesthorpe and Co.'s coal-cutting machine is now in operation at Hetton Colliery, the results hitherto are reported as favourable.

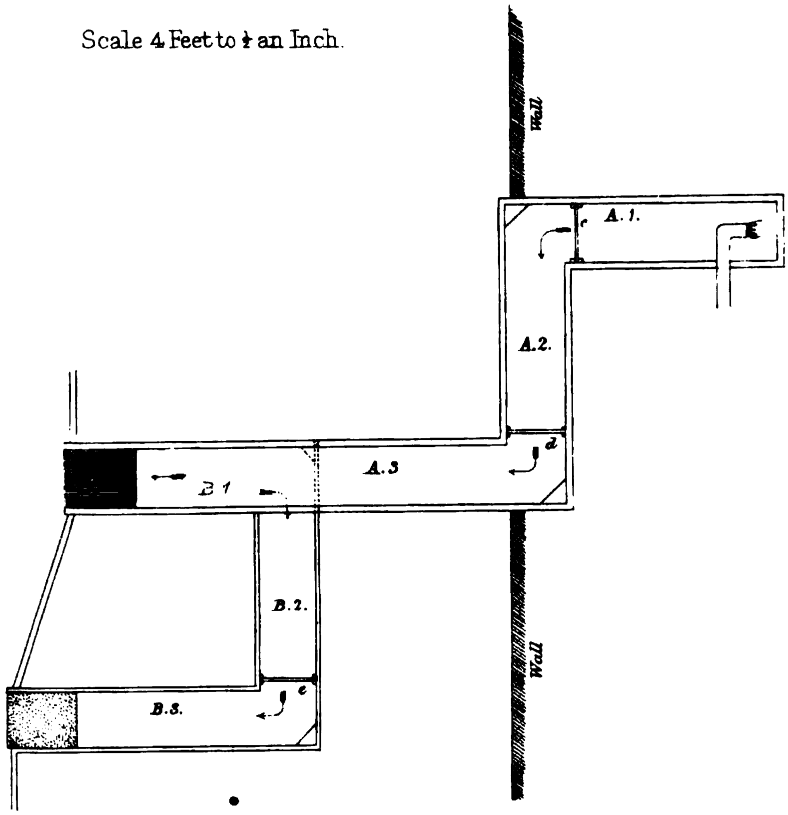
No. VIII.—WASHING OF SMALL COALS.

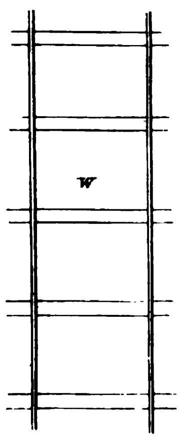
Mr. J. Morrison, a large iron master, of Sunderland, in conjunction with two French gentlemen, invented a process for purifying small coals, by washing out the impurities with which they are mixed.

COAL WASHING APPARATUS.

South Tyne Colliery.

Scale 4 Feet to ½ an Inch.





This operation is merely mechanical, and has been of the greatest importance to the northern coalowners, in enabling them to make into good saleable coke the large quantities of small and duff coals, which had formerly been burnt to waste, and thereby saving a very considerable annual amount of money.

Mr. Morrison's invention is in operation at Coxhoe, in Lancashire, &c., and it is admirably adapted to the purpose in view.

The coals are raised by means of the buckets on the endless chains (see plan), and precipitated into the basket; when the agitators force through the mass of coals a stream of water sufficient to precipitate the coals (by reason of their lightness, and their near approach to the same specific gravity as water) over the spout into the wagon; whilst the pyrites and heavier articles sink to the bottom, and are let off by a valve for the purpose.

The cost of washing a ton of coals is about three-halfpence.

The per centage of loss depends on the purity or otherwise of the coals, and on their *size*. Duff, for example, of the Hutton seam, loses about 22 per cent.; pea, small, and duff, 18; and rough small, about 14 per cent.

Another very simple mode of washing the impurities out of small coals, which has only recently come into operation, is at work at South Tyne Colliery, Haltwhistle, under the direction of Mr. John Rutherford.

The apparatus consists of an arrangement of boxes or troughs, into the upper series of which (see plan), A 1, A 2, and A 3, the water for washing is conducted by a pipe, P. At the end of A 3 is a small screen, formed of ⅜ inch round iron rod, placed about ¼ of an inch apart: immediately below this screen, another series of troughs, B 1, B 2, and B 3, is similarly arranged, terminating with a perforated zinc plate placed in a sloping position like the screen in the upper series.

The upper troughs are 2 feet 4 inches wide, and 18 inches deep: the lower ones are 2 feet 5 inches, and 6 inches deep.

At *c*, *d*, and *e*, are grooves into which slips of wood are placed, one above another, at different stages of the washing; these partially check the current of water, and assist in collecting the stones, pyrites, &c., &c.

W is the wagon-way, by which the coal is brought to the washer.

It will be observed that the pipe is bent so, that the water pours *against* the end of the trough; we find this to act better than when in the contrary direction. The mode of working will, we think, be apparent. A boy shovels the coal into the trough, and a man with a rake spreads it, and keeps it under the action of the current.

The water that passes through the screen carries a good deal of smaller coal with it. This induced us to erect the lower series of troughs, along which it is conducted, and finally passed over the perforated zinc plate.

The velocity of the current is regulated, when required, by raising or lowering the troughs, their arrangement being such, that this is very easily effected. At present the difference of level, between the pipe and the screen, is about two feet.

With this apparatus a man and a boy can wash three wagons of coal per hour. Previous to adopting this improved apparatus, the washing was done in a rough trough, about 25 feet long.

No. IX.—WASTE HEAT OF COKE OVENS.

Many efforts have at various times been made to utilize the waste heat from coke ovens by applying it to steam boilers and other like purposes, but almost in every instance it has been found that obstructions which intercept the heat and prevent the free exit of the gases from the coke oven, have proved so injurious to the quality of the coke, that no saving arising from the application of the waste heat to those purposes will compensate for the damage done to the coke.

In making coke it is essential that no obstruction should be offered to the free passage of the gases from the oven, as they arise from the coal. They should be allowed to rise freely in the oven, and to mingle with the atmospheric air in such proportions as will generate the greatest amount of heat. The coking process will thus be carried on with rapidity, producing a bright, hard, and dense coke, free from volatile matter. The admission of the atmospheric air amongst the gases in the coke oven can only be regulated by the judgment of the coke burner, whose object will always be to generate the maximum amount of heat by the best possible combustion, and to avoid, at the same time, the admission of more cold air into the oven than is necessary for that purpose.

The process of coking may be retarded by a very trifling interruption to the exit of the gases from the oven. When this occurs the coal is found to be imperfectly coked near the bottom of the oven, and the coke is thereby seriously depreciated in value. Any attempts to utilize the waste heat, which render the coke of this inferior description, will be found to be commercially valueless.

This subject has received considerable attention at Pease's West Colliery during the past five years, and after mature consideration a plan was designed for conveying the waste heat through a series of flues beneath the floor of the coke oven. The reasons which led to this mode of coking were these :—

It was known that the coal ought to produce, according to chemical analysis, 72 per cent. of coke. This, of course, is the quantity of coke that can be obtained by perfect appliances, and on a small scale.

But the coal when coked in the ordinary beehive-shaped oven yielded only about 58 per cent. of coke.

This serious waste is caused mainly by the difficulty of coking the bottom portion of the coal. The gases during the last twenty-four hours of the process, arise in such small quantities that they neither protect the surface of the coke from contact with the atmospheric air, nor generate heat sufficient to complete the coking operation. And hence the upper section of coke is consumed in the oven, in order that the bottom section of coal may be properly coked.

That the waste indicated above does occur in this manner, may be demonstrated by carefully collecting the quantity of ash and clinker that is found deposited on the surface of the coke when it is ready to be drawn out of the oven. By reckoning one hundred parts of coke wasted to seven parts of the ash and clinker, a result nearly approaching a waste of twelve to fourteen per cent. will be arrived at.

To prevent this waste as far as possible, the plan of constructing ovens with flues beneath the floor was adopted, and after a trial of them, extending over three years, it is found that the yield of coke is raised from fifty-eight per cent. to about

sixty-nine per cent. The waste heat, as it passes through the flues, is absorbed by the bottom section of coal; it penetrates through the brickwork that forms the bottom of the oven, and cokes the coal upwards to the extent of about fourteen inches. The time required for coking the coal is also much less in this description of oven than in the ordinary oven: six tons of coals can be coked in forty-eight hours, whilst in the ordinary oven it requires at least seventy-two hours to coke the same quantity. It will, therefore, be apparent, that a saving of capital in erecting a coking establishment is effected, and at the same time, several of the current expenses of manufacturing the coke are diminished by having a more compact establishment, occupying little more than half the usual area.

The question may be asked, "Can the waste heat from coke ovens be still further utilized?"

It is quite possible that this may, in some instances, be accomplished, but the difficulty to be apprehended is, that the vessel or object that is intended to absorb the waste heat will be found to obstruct the free and rapid exit and combustion of the gases, thereby producing injurious results to the quality of the coke.

No. X.—AMMONIA GENERATED IN MAKING COKE.

The experiments of analytical chemists show that coal contains about 1·5 per cent. of ammonia.

Several experiments were made at Pease's West Colliery, in the summer of 1860, with a view to collect the ammonia from the gases as they were driven off from the coal by the heat of the coke oven. The results afforded no promise of ultimate success, and were therefore abandoned.

The chief difficulty arose from having to distil the coal in the coke oven at a low temperature, in order to prevent the ammonia from being volatilized through the ignition of the hydrogen gas. After continuing the distillation in this manner for about twelve or fourteen hours, it was found that but a very small quantity of ammonia—a mere trace—had been obtained, whilst the oven had lost a great portion of the heat that was necessary for converting the coal into coke. It was found, moreover, that but a very thin layer of coal had yielded any ammonia, and that the heat that was requisite to penetrate any considerable portion of coal, so as to make it give off its ammonia, was such as to completely volatilise it as it rose to the surface of the coal in the oven. When volatilized, of course, it escaped the means that were devised for collecting it.

It may, therefore, be assumed that the ammonia that escapes from coal in the process of coking, cannot be collected with any commercial advantage in conjunction with the present method of manufacturing coke.

The foregoing statements are communicated by J. W. Pease, Esq., Darlington.

In 1848, Mr. W. Wilkinson, of Jarrow, took out a patent for "certain improvements in the construction of coke ovens, and in the machinery or apparatus to be connected therewith."

Mr. Wilkinson describes his invention as consisting of—

First.—Improvements in the construction of coke ovens, whereby the supply of air, necessary for the proper charring of the coal, is distributed, in a more equable manner than heretofore, over and through the incandescent mass, and thus increases the yield obtained from a given quantity of coal, and improves the quality of the coke produced.

Second.—In the application of machinery to the working of coke ovens, by which means a saving is effected in manual labour.

Third.—In the means of applying the heat dissipated during the carbonization of the coal to the evaporation of saline solutions.

In 1860, Mr. Thomas Ramsay, of Blaydon, took out a patent for certain improvements in making coke, the principle of which is, to grind the coal to a powder; and it is found, under proper arrangements, that a very compact dense coke is the result.

This is especially valuable, and adapted to the smelting of iron ores.

It may be inferred from the preceding, that the duff of coal, if properly freed from impurity, would form the best coke. Owing, however, to defects in the modes of burning, or to other circumstances, this question is still doubtful.

THE

METALLURGY OF THE DISTRICT.

IRON	I. L. BELL.
STEEL	T. SPENCER.
LEAD AND SILVER	DR. RICHARDSON, PH. D.
COPPER...	T. SOPWITH.
ZINC	
ANTIMONY	
ALUMINIUM	I. L. BELL.

ON

THE MANUFACTURE OF IRON

IN CONNECTION WITH THE

NORTHUMBERLAND AND DURHAM COAL-FIELD.

BY

I. LOWTHIAN BELL.

There is probably no district where the manufacture of iron is carried on which presents more features of interest, and embraces within its range greater variety, than that which is worked in connection with the coal-field of Northumberland and Durham. Notwithstanding this, the iron metallurgy of the North, which it will be the province of this paper to explain, owes none of its importance to the existence of any of the ores of iron being found in those measures which belong more immediately to its coal formation. In Scotland, Staffordshire, and South Wales, the shales of the Coal-measures contain bands and nodules of ironstone in sufficient quantity to supply immense works, established in these localities, for smelting iron. The coal-field of the North of England, on the contrary, extensive and productive in mineral fuel as are its strata, is singularly deficient in those ores of iron which distinguish many other carboniferous districts. An explanation, then, of the prominent position occupied, as a seat of the iron trade, by the locality under consideration, must be looked for in another direction, and a very brief mental survey of the geology of the adjoining country will furnish the necessary information. Starting from the coal-field itself, which, as containing the fuel required for smelting, may be considered as the keystone to the whole, we arrive within no great distance at strata which abundantly compensate for that poverty in ironstone already spoken of as inherent to our Coal-measures themselves.

The district known as the Newcastle and Durham coal-field contains an area of something like 700 square miles, and in shape may be roughly

considered as an isosceles triangle, having its apex coincident with the coast line at Warkworth. As the sea principally forms its eastern barrier, our observations are necessarily almost exclusively confined to those formations bounding it on the west and south. In the former direction, *i.e.* towards the west, a narrow strip, having a width of four or five miles, of the Millstone Grit, rising up from under the coal formation, separates this latter from an extensive tract of country, of which the Mountain-limestone is the prevailing rock. From the south-west corner of our coal-field, and separated from it by a great expansion of the Millstone Grit, accompanied by Mountain-limestone, we pass over a thin wedge of the Old-red-sandstone and enter upon the new red, to the west of which the Carboniferous-limestone again appears as a long, narrow, and curve-shaped district, extending from Penrith to Whitehaven, and of importance in describing our subject. On the south, and skirting the coal-field on the south-east, we have the Magnesian-limestone some half-dozen miles in width. Beyond it, forming for some distance the valley of the Tees, is the New-red-sandstone, separating, by an interval of twenty miles, our collieries from those hills of Lias in Yorkshire, the ore of which will occupy the greater portion of the subject of this paper.

We will now briefly allude to the position of the minerals which constituted the sources whence our furnaces in former times were supplied, adding a few remarks on their practical application; and then consider those means which at the present day furnish our greatly-extended iron works with that immense quantity of raw materials which their increased capacity demands.

We may pass over, without further notice at the present moment, both the immense beds of coal, of the purest kind, in this northern coal-field, and the inexhaustible supplies of lime furnished by the extensive tracts of Mountain and Magnesian-limestone previously alluded to. We shall, therefore, at once proceed to name the different combinations in which ironstone is found in the various strata of the measures already referred to, reserving any further remarks when we come to speak of the composition and nature of the minerals generally.

IRONSTONE OF THE COAL MEASURES.

Many of the numerous beds of shale associated with the coal formation in this neighbourhood contain, interspersed in their thickness, nodules of ironstone, but these have rarely been sufficiently abundant to lead to their being worked for smelting purposes.

Above the seam of coal known on the Wear as the High Main, and

separated from it by a distance of eighteen inches, is a continuous band of this ore. It is four and a half inches thick, and was formerly wrought on Waldridge Fell for the Whitehill Iron Works, and subsequently at Urpeth and its vicinity, for the furnaces at Birtley. Another thinner band, only two inches in thickness, formed the roof of the Huttom seam, near Birtley. From the fact that both these were extracted by simply bringing down the roof of the old coal workings, it was expected to supply the furnaces there at a very cheap rate, and this might have been so had the quantity per acre been larger. As it was, the ironmasters had to seek far and wide for supplies, and, in consequence, the cost of stone was ruinously high. The present partners in the Birtley Works have kindly placed in the writer's hands their cost-book, and from it, after the furnaces had been in operation four or five years, the following results are taken :—

	Ironstone used per Ton. Cwts.	Qrs.	Lbs.	Cost on Ton of Iron. £	s.	d.
1835	65	0	19	2	18	1½
1836	67	1	5	1	17	6½
1837	71	0	27	2	7	3¼
1838	67	0	17	2	2	8¾

From their furnace books this appears to have represented the calcined weight, and hence the yield of the raw stone must have been from 25 per cent., gradually falling to 22. At this time hot blast was in use at the Birtley Works, the system having been introduced there about 1831. Mr. George Clayton Atkinson, a partner of the Tyne Iron Company, has obligingly given the following as their consumption for the year 1812, using stone of a similar kind to that described above; indeed, a considerable quantity was purchased from the owners of the Birtley Iron Works, previous to the erection of the establishment at that place. The quantity used was 8772 tons, which cost on an average 16s. 1d. per ton. During that year they produced 2547 tons 18 cwts. of iron, and, in addition to the above-mentioned ironstone, there were consumed 284 tons of hematite. If the small quantity of this latter ore is assumed to give 50 per cent., the yield of the clay ironstone would be something above 27 per cent. The difference in the produce may have arisen from less perfect freedom from adhering shale in the Birtley furnace workings—a supposition corroborated by the increased consumption there to the ton of iron in later years, when failing supplies would prevent proper "weathering" of the ironstone. In 1812, the ironstone per ton of iron cost the Tyne Iron Company £2 18s. 10d.

Near Wylam, according to Mr. Benjamin Thompson, who erected the works at that place, a mine was opened in 1836, out of which, from a section of 4 feet, four bands, measuring together 10½ inches, were obtained. This cost, it was stated, 7s. 6d. per ton of 22½ cwts., and yielded 30 per cent. of iron. Another working supplied nodules, having a per centage of 35 to 37, and costing 11s. 6d. per ton. The united produce, however, of both did not suffice to supply 150 tons weekly, and these mines were speedily abandoned when a less precarious mode of obtaining ironstone offered itself, although the cost of the latter would, at the period of its first introduction, have not been less than £2 on the ton of iron.

At Shotley Bridge, on the western edge of our coal-field, and consequently low down in the series, is a deposit of ironstone, which has been far more extensively worked than any other seams found in our Coal-measures. According to a description by the late Mr. William Cargill, in a working having a section of about 7 feet in height, 12 to 15 inches of stone were obtained from six or seven bands. The ironstone from it cost 7s. to 8s. per ton. At a depth of 4½ fathoms below it, and lying above 20 inches of coal, is a bed of shale about 3 feet thick, containing 6 to 7 inches of ironstone. The total yield of both seams, contained in an acre of ground, Mr. Cargill estimated at 5324 tons. In later years, however, according to a detailed report communicated by Mr. Edward T. Boyd, the average produce of the first-mentioned seam, "The Ten Band," as it was called, at that time was 8 inches of ironstone in a working 5 feet 9 inches high, and in the other bed his section gives—

	Ft.	In.	Ft.	In.
Good coal	1	6		
Splint ditto	0	7		
			2	1
Ironstone	0	4½		
Shale	3	6		
			3	10½
			5	11½

For a limited supply, the quantity of ironstone found in this neighbourhood might have sufficed; but an immense work having been erected upon it, comprising 14 blast furnaces, serious inroads were soon made on its resources. From information formerly received, it would not appear, whatever might be the richness of clean stone, that its yield, as delivered to the furnaces, exceeded 26 per cent. The cost on a ton of iron, for ironstone, at Shotley was 25s. to 30s., which compelled the

owners of this establishment to look to another district for their supplies, so that at the present time every pit on their royalties is laid in.

A small quantity of ironstone continues to be extracted from a land-sale colliery at Hedley, which is smelted at Wylam, and, as the writer believes, some is still worked by the Weardale Iron Company near Tow Law. In a general sense, however, it may be assumed that ironstone of the coal formation of the North of England forms no element, at the present day, in the consumption of the blast furnaces of that district.

THE IRON ORES OF THE MOUNTAIN LIMESTONE.

Following the order of our description of the geology of the country, the deposits of ironstone connected with the mountain limestone next demand notice. In this series there occurs a bed of shale 30 feet in thickness, in the whole of which considerable quantities of nodules of ironstone are interspersed. The late Mr. Thomas J. Taylor, in evidence on the Border Counties Railway Bill before a Parliamentary Committee, in 1854, stated this shale bed to contain 9680 tons of ironstone to the acre, of which he assumed practically 6000 could be obtained. Its cost he stated to be 6s. 6d. to 7s. per ton, and its yield such as would require 3¼ tons of stone to produce one ton of iron, equal to 30·5 per cent. Mr. Benjamin Thompson, who worked this bed at Hareshaw, informs the writer that 8470 tons of ironstone per acre was its contents, and of this the lowest 6 feet contained two-sevenths of the whole. Allowing one-third for loss, he considered 5647 tons as the practical produce of an acre. Its yield he gives as 33 per cent., and its cost 9s. per ton of 22½ cwts., equal to 8s. per ton of 20 cwts. At Redesdale, from data possessed by the writer, the cost of ironstone for a ton of iron was 29s. 3d. This deposit has been somewhat extensively wrought at Hareshaw and Redesdale, as well as attempted at other places. In all these localities, however, the workings have been discontinued.

At Chesterwood, about two miles from Haydon Bridge, there was opened out, some years ago, a seam of what in some measure resembled the famous "black band ironstone" of Scotland, containing, however, much more coal than the celebrated ore of this name. It varied, according to Mr Bigland, who worked it, from three to four feet in thickness. The raw stone contained 20 to 25 per cent of iron; but instead of two tons of raw mineral producing one ton of calcined, as in the case of Scotland, three tons were required at Chesterwood; so that the richness of the calcined stone was about the same, viz., 60 per cent.

Mr. Bigland states that for several years they obtained 20,000 to 25,000 tons of the raw stone, until the bed was exhausted in that locality in 1855, after less than ten years' working. The deposit has been traced to other places, but in each case it is thin and poor in metal.

In Alston Moor many of the mineral veins traversing the mountain limestone contain a considerable quantity of a hydrated peroxide of iron, as well as amorphous carbonate of iron. A bed of the latter, lying on the surface, but of very limited extent, was worked by the writer's firm at Nenthead, and smelted at Wylam. The iron produced from it, as well as from other carbonates and oxides from the same district, was of excellent quality; but unfortunately the supplies were too uncertain and too costly. The ore in the veins themselves at one time was tolerably pure carbonate, yielding perhaps 30 per cent. or more of iron; but it gradually passed into carbonate of lime, from which it was with difficulty distinguished. At the present day, only a small quantity is worked at Alston. On the other hand, at Weardale the veins contain so much carbonate and oxide of iron that furnaces have been erected at Tow Law, by Messrs. Attwood and Baring, for their reduction.

The small district of mountain-limestone spoken of as stretching from Penrith to Whitehaven, contains very large quantities of most valuable red hematite, containing 60 per cent. and upwards of iron. It is sold at Whitehaven at about 10s. per ton. Its position is uncertain, in a mining point of view, occurring in detatched masses of varied thickness. This locality, as well as that near Ulverstone, of a similar character, is of importance in connection with the northern coal-field, inasmuch as considerable quantities of the hematite ore are brought over to the east coast as a mixture with our own ironstone; while, to the furnaces smelting the produce of the Whitehaven mineral field, coke from our side is conveyed.

IRON ORES OF THE LIAS FORMATION.

The lias rocks of Yorkshire constitute by far the most important source from which the needful supplies for our furnaces are derived. The seams of ironstone belonging to this formation crop out on a considerable extent of the coast line of the shale beds, which, in addition contain large balls of the same ore. In rocks so liable to disintegration from atmospheric influence, these have fallen away, and, in consequence, considerable quantities of ironstone, freed from the adhering shale, are to be found on the beach as rounded pebbles, and even as masses of rock. In modern times, the ore so separated from its parent bed attracted the

attention of those ironmasters who had commenced smelting the ironstone of the coal-field. Mr. Joseph Cookson, in a very interesting document drawn up for the writer, mentions that, for the Whitehill furnace, built in 1745, and abandoned before the end of last century, ironstone was gathered in Robin Hood's Bay, and conveyed by water to Picktree, on the Wear, near Chester-le-Street, and carted from that place to the works. Soon after the year 1800, the Tyne Iron Company obtained ironstone in a similar way from the beach between Scarborough and Saltburn; and, according to Bewick, in his work on the Cleveland Ironstone, that firm commenced, between the years 1815 and 1820, to tear up the stone from its bed at different parts of the coast. The exposed character of the Yorkshire shores, and want of shelter, rendered the conveyance of ironstone to the Newcastle furnaces a task of great difficulty and of some danger; and it was, therefore, not until the stratum furnishing it was discovered inland, on a line of railway at that time recently opened, that any large quantity of this lias ironstone was consigned to the ironmasters of the Tyne. It is stated that the discovery of this bed is due to a Mr. Wilson, then a partner in the Tyne Iron Company's Works, who pointed out its position at Grosmont, about five miles from Whitby, in 1836. The seam being 4½ feet thick, was cheaply worked, sent down the railway, and shipped at all seasons for the Tyne, where it would, at that time, cost about 9s. per ton. It is probable that, ultimately, as much as 80,000 to 100,000 tons of it were annually smelted in the north country furnaces.

Much surprise has been expressed at the time which elapsed between this discovery in 1836, and the period when the importance of the bed of ironstone became so immensely increased by the large quantity of ore extracted from mines opened in it since 1850. This is not so difficult of explanation as might at first appear. The Whitby ironstone, as it was then generally called, was known over a distance of coast not far short of ten miles, and its character to the west, five miles inland, had been also sufficiently explored. Over the whole of this area its yield of metal had been uniform, viz., about 25 per cent. No doubt the owners of the blast furnaces, which had been built on the Tyne for smelting local ores, were too glad to obtain a cheaper stone elsewhere, particularly when hot blast increased the consumption of their furnaces, already indifferently supplied, and competition with Scotland ran down the price of iron. Whitby harbour, for these firms, was more convenient than the Tees, because vessels coming down in ballast more easily ran into the former

than up the somewhat intricate navigation of the river, and there was no reason to suppose that a seam of ironstone, which had so uniformly maintained a low per centage over fifteen miles of country, should, in this respect, as well as in others, change so rapidly in the next dozen miles. That the introduction of the stone from Whitby did not confer any great advantage on the Tyne smelters is proved by the fact that, for fourteen years after its discovery, only two furnaces, and those built under somewhat peculiar circumstances, were added to the five in blast previous to the importation of this ore. The fact was that, with the exception of one or two years, the Tyne never could compete in selling "mine" iron against the market price of the Glasgow makers. No practical man, therefore, was likely to be led into the expenditure of capital by a year or two's prosperity, with the knowledge of the superiority conferred on his Scotch competitors by their fields of black band. Between the years 1840 and 1850, the cost of ironstone on the ton of iron was never, at the Birtley Iron Company's Works, less than 26s. 3d., and this only when the trade was in an exceedingly depressed condition; 30s., and as high as 34s., was the more ordinary figure. The average selling price of iron at Glasgow, over eleven years was within 6d. of the cost at the Birtley Iron Works, and to obtain this the owners must have charged the coal from their own pits at less than 2s. per ton laid down at the furnaces. During five years of the eleven, iron was cheaper at Glasgow than the cost at Birtley, even with the coal supplied at 1s. 6d., or thereabouts, per ton. In 1845, both the owners of the Walker and of the Tyne Iron Works sought to mend their position, by looking for royalties of black band in Scotland, and, in consequence, there was brought for some time a considerable quantity of that mineral to the river Tyne.

Matters were in this state when Messrs. Bolckow and Vaughan, who, in 1840, had built a rolling mill at Middlesbrough, added, at Witton Park, in 1846, the process of smelting to their operations. They were induced to do so by an offer of ironstone to be supplied from the coal-field near Bishop Auckland. In these expectations, as had happened to their colleagues on the Tyne, they were disappointed, and like them, they had recourse to Whitby. In one respect, however, their position differed from that of the ironmasters further north. In a voyage of fifty miles, ten miles more or less is a small sacrifice compared with securing a good harbour, but where the ironstone measures were known to run close to the mouth of the river upon which the works were placed, it was obviously a matter of importance to draw the supplies of ore, or as much of it as

could be obtained, from the nearest point. Examination of large detached masses which had fallen from the cliff led Messrs. Bolckow and Vaughan to Skinningrove on the coast, at which place, to their surprise, they found the bed had thickened out from 4½ feet to nearly 14½, and instead of 25 per cent. of iron, it contained 31. So far was accident; but that firm experiencing the usual inconvenience arising from an exposed place of shipment, sought for, and found in 1850, the position of the ironstone inland. It is not pretended that the merit of original discovery belongs to Messrs. Bolckow and Vaughan in reference to this extraordinary deposit of ore. On the contrary, Mr. Jackson, the father of the present owner of Normanby Hall, sent, in 1811, two wagons of it to the Tyne Iron Works. Mr. Bewick, senior, was also, a year or two before its position inland was recognised by Messrs. Bolckow and Vaughan, aware of its existence near Guisbro'. Indeed, so early as 1839, a Mr. Neasham had despatched an entire cargo to the Devon Iron Works at Alloa, in Scotland, at which establishment it met with an indifferent reception, being tipped over the rubbish-heap very soon after its arrival. In the minds of none of these gentlemen, however, did the mineral excite that confidence in its value which the subsequent labours of the Middlesbrough firm ascertained it possessed, and to whom undoubtedly is, therefore, due the merit of having introduced it to the immensely important place it now occupies. The lias rocks contain other beds of ironstone, to which reference will be hereafter made, when the composition of the Main Cleveland seam, and its use as an ore of iron are spoken of.

We have thus seen that in a district embraced within the four counties of Northumberland, Durham, Cumberland, and Yorkshire, the coal formation contains the usual clay ironstone; the mountain limestone has furnished to a limited extent some black band and nodules of ironstone, and is now affording spathose ore and brown hydrated peroxide of iron, as well as very large quantities of the finest red hematite; lastly, in the lias beds of Yorkshire there are found inexhaustible deposits of an argillaceous ore. Besides all these, and profiting by the return of light colliers, some small quantities of other ores, both foreign and British, are conveyed to the Tyne, but not to an extent to render them worthy of more especial notice. The composition of the various minerals now in use will be given when the subject of their metallurgical application comes, in its proper place, to occupy our attention.

HISTORICAL ACCOUNT OF THE MANUFACTURE OF IRON IN THE NORTH OF ENGLAND.

It is now proposed to show in what order, and in what manner, the various ores of iron, met with in the different geological measures in the North of England, have been made available in a metallurgical point of view.

Before entering on this part of his task, the writer would take the opportunity of expressing his acknowledgments to Mr. Hodgson Hinde, to whose antiquarian researches he owes some valuable information respecting the earlier production of iron in the North of England.

Notwithstanding the varied character of the different ores of the district under review, and the want of indication of metallic contents of some, the property that even these have of "rusting" on exposure to air and moisture appears to have made known the existence of all at a very early period of our history. The labours of Hodgson, Wallis, and others, leave little or no doubt that the smelting or reduction of iron ore was carried on to a considerable extent in this part of the country during its occupation by the Romans. Vast heaps of iron scoriæ may be seen on the moors in the parishes of Lanchester and Chester-le-Street, in the county of Durham, and in the valleys of the Reed and the Tyne, on the mountain limestone, in Northumberland. It is remarkable that none of these are very remote from one or other of the Roman stations which are scattered over these two counties. The same observations respecting an early use are, to some extent, applicable to the lias ironstone, and no doubt proper investigation would indicate a similar state of things wherever iron ores were near the surface, and the state of society required the metal they contained. That furnaces, or "bloomeries," were continued or re-established in some of the same situations, is proved by an inquisition of the death of Gilbert d'Umfraville, Lord of Redesdale. In the catalogue of his possessions, A.D. 1245, there are mentioned, "forgiæ quœ reddunt ferrum, quod reddit per annum iiij l ijs;" and that iron works existed in the county of Durham in the early part of the 17th century appears from a curious tract written in 1629, entitled "A Relation of some Abuses committed against the Commonwealth, composed especially for the county of Durham." The author, who signs his initials "A. L.," instances as the first abuse the great destruction of timber, chiefly for the sake of bark for the tanneries, but in one instance, at least, for smelting operations. He says, "There is one man, whose dwelling-place is within twenty miles of the city of Durham, who has brought to the ground (to

omit all underwood) above 30,000 oaks in his lifetime, and (if he live long enough) it is doubted that he will leave so much timber in the whole county as will repair one of our churches if it should fall, his iron and lead works do so fast consume the same."

Hitherto, of course, all these smelting operations have reference to the small bloomery or hearth in which, with a little ore and some charcoal blown by the wind in exposed situations, or subsequently by rude bellows, a "bloom" of malleable iron was obtained.*

The German colony of ironworkers at Shotley Bridge established themselves at that place in the reign of William III. At some time or another afterwards a small high-blast furnace, five or six feet in the boshes, was erected there, the remains of which, according to information received, are still visible. Wallis, in his History of Northumberland, published in 1769, mentions an iron work which existed some years previously at Lee Hall, near Bellingham, under the management of a Mr. Wood, "who made a good deal of bar iron, but charcoal becoming scarce, he removed to Lancashire, where he attempted (unsuccessfully) to make it with pit coal." Although bar iron only is mentioned, there is no doubt, from the remains still existing, that Wood also produced pig iron. Charcoal iron was also smelted from some of the bands of clay ironstone at Bedlington, where the old calcining kilns are still visible, or were so until very recently. No iron, however, has, as far as can be ascertained, been made there for more than a 100 years.

The inroads which iron smelting, together with other metallurgical operations, &c., had made upon the forests were such that, in the reign of Queen Elizabeth four Acts of Parliament were passed to restrict the consumption of timber, especially when applied to the manufacture of iron. To supply the deficiency thus occasioned, schemes were proposed so early as 1612, by Sturtevant, and subsequently, in 1621, by Dud Dudley, for smelting iron with pit coal. The unsuitability, however, of the arrangements in use for smelting with charcoal, when applied to

* This simple mode of smelting, viz., the bloomery, is the one which appears to have been universally adopted in the first instance for obtaining iron. Captain Grant, who has recently returned from his expedition to the source of the Nile, found the inhabitants of the Land of the Moon gathering small nodules of ironstone from the sides of the hills, and smelting them on the bare ground in a charcoal fire. The blast was produced by two or four persons working each a small bellows formed of wood and goat skins. At the end of the wooden bellows-pipe was a short tube, or tuyere, of baked earthenware, which conveyed the compressed air to the fire. The bloom resulting from the operation was beaten into a thin bar and then drawn out into wire, which was chiefly used for ornamental purposes.—*Private Letter to the Writer from Captain Grant.*

mineral fuel, in all probability delayed this important amelioration taking effect for a 100 years after its first suggestion by Sturtevant. The small furnaces and bellows of very limited power, which did very well with charcoal, would be literally useless when applied to coal or to coke. After various ineffectual attempts by Buck and others, about 1713 the Darbys of Staffordshire reduced the application of pit coal to one of practical utility in that county. Darby's progress, however, must have been slow and his success limited, for the number of blast furnaces in the country had, in the meantime, decreased from 300 to 59, so that in 1740 the make of pig iron in England had fallen to 17,850 tons, from about 180,000 tons—the chief portion of our requirements being imported from Sweden and Russia. To Mr. I. Cookson, who had recently purchased the Whitehill estate, near Chester-le-Street, the merit belongs of erecting and working the first blast furnace with coked coal in the North of England. The Whitehill furnace was 35 feet high, 12 feet across the boshes, and produced 25 tons of iron per week. The blast was supplied by a bellows, worked by a water wheel placed on Chester Burn. Its mode of supply of ironstone was from the thin bands on Waldridge Fell, and from Robin Hood's Bay, as has been already mentioned. The coal, of course, was obtained from the immediate vicinity. Mr. Joseph Cookson, a descendant of the founder of pit coal smelting in this district, has given many curious particulars respecting this early attempt. The iron was used for colliery castings, and latterly for Government ordnance. Frequent interruptions, for want of water to drive their wheel, led at length to the furnace being "gobbed," and ultimately abandoned, about the close of the last century.

Whatever advantages, in point of minerals, any district might stand possessed of, its power for turning them to profitable account depended at that time on the existence of a fall of water sufficient to drive the needful blowing apparatus. The discoveries of Watt prevented the want of hydraulic power being any longer an impediment, and in a short time the obedient steam engine was appointed to supply the necessary blast to iron furnaces. Notwithstanding the poverty of our coal-field in ironstone, the high price of iron (£8 per ton) and the small quantity of ore required for a furnace, when 40 tons of iron was the usual week's make, induced the Tyne Iron Company, in 1800, to erect their two furnaces and a steam blowing engine at Lemington. An idea of the cost of manufacturing pig iron in those days is not without interest, as illustrative of the disadvantages of this coal district as an iron-field. The

particulars are kindly furnished by Mr. G. Clayton Atkinson, one of the present members of that firm, so that their correctness may be relied on.

Ironstone	3·44 tons	at 16s. 1d.	£2 15 5		
Hematite ore	0·11 „	81s. 6d.	0 3 5		
				£2 18 10	
Flux (chalk)	1·38 „	2s. 0d.		0 2 9	
Coke	2·40 „	12s. 5d.		1 9 9	
Labour, &c.				0 14 2	
				£5 5 6	

These details are of the year 1812, when cold blast alone was employed. The make from one furnace was 2547 tons; equal to 49 tons per week. The ironstone, with the exception of 806 tons of "beach stone," was all the produce of the thin bands of our coal measures.

In 1825, pig iron rose in value to the unprecedented price of £12, and as a considerable portion of the stone smelted by the Tyne Iron Company was the produce of pits at Urpeth and its neighbourhood, Messrs. Perkins, Hunt, and Thompson, who were extensively engaged in coal mining in that locality, blew in two furnaces in 1830, which they had built at Birtley. Their operations, like those of their predecessors at Lemington, exhibit, with equal force, the absence of the elements of success in our coal-field for the manufacture of iron, even when the fuel was supplied to the furnaces at the low rate of 2s. per ton or less. The following is copied from their cost-book, and represents the workings for two furnaces for 1835, when hot air was used—an improvement introduced at Birtley in 1831. The make was 4390 tons, or only 42 tons for each furnace per week. The cost per ton of iron was, for—

Ironstone	£1 18 1¼
Flux (chalk)	0 2 7
Coal (five or six tons probably)	0 7 0¼
Labour, &c.	0 14 2¼
Sundries	0 14 2
	£3 16 1

In 1836, the furnace at Wylam was put into blast by Messrs. Thompson Brothers to smelt ironstone, expected to exist in great abundance there, as has been already explained.

We have now arrived at that period in our history of the iron trade which was followed by a gradual, but, ultimately, an entire change in the sources from which the furnaces of this district derived their supplies of ironstone. So early as 1836, a cargo of that ore, which in time dis-

placed all others at the then existing works on the Tyne, so far as local ironstone was concerned, was sent from Grosmont, near Whitby, to Birtley. In the year 1833 and up to 1839, pig iron had ranged from £4 10s. to as high as £9 per ton in Wales. The demand for iron in this neighbourhood was so vastly on the increase, that the ores of the coal strata could not meet the growing requirements, and the Whitby stone had not inspired much confidence either for economy or quality of the iron it produced. In consequence, speculators began to pay attention to those deposits of ironstone spoken of as being connected with the mountain limestone. Redesdale was the place selected by Mr. Stephen Reed, Mr. Thomas Hedley, and others, where the stone existed, as has already been described, and where coal could be obtained from a seam from 2 to 2½ feet thick, situated in the same geological formation.

Although pig iron had fallen in 1840 to £3 12s. 6d. at Glasgow, and in 1841 was selling at £3 5s. per ton, a second work, to smelt the same bed of ironstone with the coal 2½ feet thick, lying 70 fathoms below the ironstone, was put in blast at Hareshaw; a second furnace was subsequently built at Redesdale, and two more at Hareshaw. There is no doubt that the iron produced from this bed of ironstone was of a very excellent description. Both works, however, were nearly twenty miles from a railway, and twenty more from a market, so that their iron cost, according to Mr. T. J. Taylor, 12s. per ton for carriage to the consumer. After some years of fruitless struggle to meet the competition offered by Glasgow, both of these establishments were closed and finally dismantled.

About 1840, Messrs. Bigge, Cargill, Johnson, and others, who had purchased from the projectors of the Redesdale Works that concern, had their attention directed to the beds of ironstone described as lying in the coal measures near Shotley Bridge. A pair of furnaces were speedily erected and set in blast. A larger company was formed, and an immense establishment was constructed. Twelve blast furnaces were built, large rolling mills and all the necessary mines, mining villages, &c., followed in rapid succession. Until 1850 the furnaces went on devouring the minerals found in the neighbourhood at an alarming pace, having in the meantime made extensive trials of those from the lead veins of Weardale. In 1850, the recent discoveries in Cleveland promised relief from the impending famine, and in a very short time, in spite of a distance of about fifty miles, the ironstone from that district, with some hematite for a mixture, entirely superseded the stone lying adjacent to the furnaces.

In 1842, Messrs. Losh, Wilson, and Bell, who for fifteen years had

been making bar iron, built a blast furnace at Walker for producing forge pig by smelting their mill-furnace cinders with Whitby stone, and this was followed by a second one in 1844, so that these were the first furnaces ever built expressly for smelting the recently-discovered ironstone at Whitby.

About this period, Mr. Charles Attwood, in concert with Messrs. Baring and Co., of London, purchased a small furnace then recently erected at Stanhope by Mr. Cuthbert Rippon, and built five others at Tow Law for smelting the "rider ore" (carbonate and oxide) of the lead veins. There is no doubt, that owing to the extreme irregularity of this kind of material, immense labour and expense were at first incurred, and, as regards the quality of the produce, frequently with very unsatisfactory results. Better acquaintance, however, with the veins and their contents, has enabled that firm now to produce iron of a very high class—so good, indeed, as closely to resemble in composition and quality the celebrated German "Spiegel Eisen." For bar iron purposes it bears a high name, and has, like its prototype in Germany, been found well adapted for the manufacture of the finer kinds of steel, an application, as is well known, confined exclusively to the purest descriptions of metal.

In 1846, Messrs. Bolckow and Vaughan erected the furnaces at Witton Park, in the Auckland district, for smelting ironstone expected to be obtained in that vicinity. We have already heard how these hopes were disappointed, and Whitby resorted to, as it had been by almost every furnace owner in the north.

Although only remotely connected with our subject, it may as well be mentioned that a company of gentlemen had erected at Cleator Moor, near Whitehaven, a couple of blast-furnaces for smelting the hematite iron ore of that district, an example which has been somewhat extensively followed since. The iron made is of good quality, and, the ore being rich, an immense quantity, as much as 500 tons weekly, or more, is said to have been run from one furnace.

To avoid interrupting the remainder of our subject, which will hereafter be confined almost exclusively to the Cleveland stone, mention may be made of other trials to render available the bed of ironstone nodules of the mountain limestone. This was attempted at Brinkburn, on the Coquet, but after a very short trial the works were closed. Another experiment was made at Haltwhistle with a similar view, but it also was abandoned soon after the erection of the works.

At Bedlington, two furnaces were constructed to smelt the same bands,

formerly used at the charcoal works in that locality, with an admixture of Yorkshire stone, mill cinder, and other materials, but these also were only a short time in operation.

We have now arrived at the period when the newly-discovered Cleveland bed of ironstone was about to supersede all other modes of supply of this mineral, and the present will therefore be a convenient opportunity of estimating the position of the iron trade previous to its introduction. This will be most readily done by glancing at a list of the furnaces then in existence, which were as follows:—

Furnaces.	Proprietors.	No.	Description of Ironstone used.
Lemington	Tyne Iron Co.	2	Whitby stone, black band, and hematite.
Birtley	Birtley Iron Co.	2	Whitby stone, &c.
Wylam	Bell Brothers	1	Do, black band, hematite, &c.
Bedesdale	Redesdale Iron Co.	2	Nodules from the mountain limestone formation.
Hareshaw	Hareshaw Iron Co.	3	Do. do.
Shotley Iron Works	Derwent Iron Co.	14	Bands of ironstone from coal measures, and hematite.
Walker	Losh, Wilson, & Bell	2	Whitby stone, black band, hematite, &c.
Towlaw & Stanhope	Weardale Iron Co.	6	"Rider ore" from lead veins, and a portion from coal measures.
Bedlington	Longridge & Co.	2	Whitby ironstone, and a portion from coal measures.
Witton Park	Bolckow & Vaughan	4	Do. do.
	Total	38	Furnaces

The entire make of all the furnaces would never exceed 150,000 tons per annum during the period under consideration.

We have now (*i.e.* A.D. 1851) brought up the account to what substantially in principle is the position at present occupied by the manufacture of iron, on or in connection with the Newcastle and Durham coal-fields. In pursuing the narrative illustrating the development of the trade, it will be convenient to give, in the order they arise, some account of the character and composition, both of the raw materials used and of the products obtained.

COAL.

Notwithstanding the varieties of coal which occur in the Northern Coal-field, the whole, with few exceptions, are more bituminous in character than the produce of other localities in this country. North of

the Ninety-fathom Dyke, is the district where the Low Main of the Tyne (Hutton seam of the Wear) furnishes the least caking coal we possess, but even here the small coal when coked loses all trace of its original form, and leaves the ovens as large masses of coke. At Wylam, Walbottle, and other places, a thin layer of a dry burning splint coal does occur in connection with a seam of a highly caking description, but the entire quantity of it, and of any other similar variety, is very insignificant. The caking property, although very valuable for many purposes, entirely unfits the coal of this district for use in the raw state in our blast furnaces, where its fusing property, by impeding the blast, causes the contents of the furnace to hang and slip, and thus to descend at irregular intervals. Against this disadvantage, however, possessed by our coal, may be placed the extreme hardness and strength of the coke it produces, which is thereby rendered capable of resisting the crushing effect of a high column of materials as they exist in our blast furnaces. An experiment at the Clarence Works showed that a cube of coke, two inches on a side, supported a weight of twenty-five cwts. when cold, and twenty cwts. when hot, before it was crushed. Dr. Richardson gives the following analyses of coal from this and other districts, the latter being given for the sake of comparison :—

	Locality.	S.G.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Per centage Coke left by Coal.
18 Samples,	Newcastle	1·256	82·15	5·31	1·35	1·24	5·69	3·77	60·67
36 Do.,	Wales	1·315	83·78	4·79	0·98	1·43	4·15	4·91	72·62
8 Do.,	Scotland	1·259	78·53	5·61	1·00	1·11	9·69	4·03	54·22
7 Do.,	Derbyshire	1·192	79·68	4·94	1·41	1·01	10·28	2·65	59·32

The purity of the coal is by no means an infallible indication of its fitness for the manufacture of a suitable coke for iron furnaces. Not only are comparative freedom from ash and sulphur indispensable, but we must have concurrently the power, which depends on some circumstance we do not clearly understand, of producing coke sufficiently compact to come down to the region of fusion in our furnaces, without being much crushed on its way.

To form an idea of the extent to which ash and sulphur exist in the coke of the South Durham Coal-field, the following analyses are extracted from the Clarence Laboratory journal :—

Ash Per Cent.	Sulphur Per Cent.
5·86	0·58
5·79	0·68
7·54	0·77
9·00	0·44
8·33	0·50

As a rule, 6 per cent. of ash and about 0·60 of sulphur may be considered as the average analytical results of the best coke of the district just quoted. Following the example of our neighbours abroad, plans have been introduced into this neighbourhood of submitting coal of an inferior description to a washing process, by which, where the earthy matter is not part and parcel of the coal itself, a very large quantity of impurity is easily removed.

LIMESTONE.

A very few words will exhaust this section of the subject. In certain districts the Magnesian-limestone, although differing little in colour, &c., from the rock in other localities, is nearly entirely carbonate of lime, and the Mountain-limestone almost invariably, from its purity, satisfies the conditions required by the iron smelter. These two, but principally the latter, with a little chalk, brought by coasting vessels as ballast, constitute the flux in the iron furnaces. The following analyses from the Clarence Laboratory show the composition of—

	Mountain Limestone, Harmby.	Magnesian Limestone, Raisby Hill.	Chalk from South of England.
Insoluble in hydrochloric acid	2·00	0·95	1·96
Peroxide of iron and alumina	0·98	0·40	1·24
Lime	53·35	54·62	53·84
Magnesia	1·08	0·43	0·63
Carbonic acid	43·02	43·42	42·99
	100·43	99·82	100·66

The chalk contained twenty-one per cent. of water.

IRONSTONE OF THE LIAS.

It will be foreign to the intention of the present communication to attempt anything like a minute description of the district over which the deposit of ironstone, embraced within the title of this section, is found. Mr. John Marley, whose name has been, from the first, associated with its discovery in the neighbourhood of Middlesbrough, and who has devoted much attention to its geological position and extent; and the late Mr. Joseph Bewick, to whom a long practical acquaintance with the subject gave abundant opportunity of studying this question, have both written on the subject at considerable length. To their works—the former in the Transactions of the Northern Institute of Mining Engineers, and the latter in a work on the Cleveland Ironstone—those persons who desire more detailed information are referred.

It may be, however, briefly stated that Mr. Bewick gives the dimensions of the field of ironstone as thirty miles by sixteen, from which he deducts sixty miles for denudation, giving a net area of 420 square miles. The brother and partner of the writer, Mr. John Bell, who possesses a very complete knowledge of the district, prepared models and maps of the country, which agree pretty closely with these estimates. Mr. Bewick roughly considers the yield to be 20,000 tons per acre, and hence infers that close on 5,000 million tons are contained in the Main Cleveland seam, within the limits laid down.* We have already seen in the preliminary account of this bed of ironstone how varying in thickness it is. In some places, also, it becomes more or less split up by bands of shale, a circumstance which of course interferes greatly with its commercial value. Commencing with Grosmont, near Whitby, where it was first wrought in a systematic way, there are found two seams of ironstone known as the Pecten and the Avicula bands. The former consists of 3 feet of ironstone, divided in the middle by a bed of shale 1½ feet thick. Separated from this by 30 feet or more of shale, is the other seam, the Avicula, embracing 4½ feet of ironstone, along with 2 feet of shale; and it is by these two bands uniting, as well as increasing in thickness, that we have, further north, the Main Cleveland seam, as it is termed. In the northern portion of the field considerable irregularity in character is also observable. At Codhill the bed has an extended height, but is so interspersed with foreign matter that it is found necessary to confine the mining to a section of 5½ feet; and the produce, from the circumstance of more or less shale bands running through the ironstone itself, is only about 28 per cent. of metal. A little to the east of Codhill are the Belmont Mines, where the shales thin out, and in consequence, the yield of iron is about 30 per cent., the seam at the same time having increased in height to 7½ feet. At Skelton, still further east, a marked improvement, both in thickness and in quality, is again discernible. The workings there are frequently 10 feet high, and a recent analysis of the entire section of stone gave about 36 per cent. of iron. The north side of the vale of Guisbro' is formed by an elevated ridge of land separating this valley from that of the Tees. At the western edge of this ridge are

* In an estimate recently made by the writer, based on the researches of Messrs. Hugh and T. J. Taylor, T. Y. Hall, &c, there would appear to be in our northern coal-field six thousand million tons of coal left for future use; so that there is just about fuel enough in the one district—reserving it for that purpose exclusively—to smelt the ironstone of the main seam of the other.

the Normanby Mines, where the stone is worked at an average thickness of about 8 feet, containing 31½ per cent. of iron. There is a general dip of the seam to the east from this point, and in its progress in that direction there is a gradual increase in thickness, and a little improvement in per centage of iron. It continues in this way past Eston and Upleatham, until it reaches Rockcliffe, where it attains a thickness of nearly 18 feet, after which it splits again into bands, and as far as is known, resumes towards the east and south the character formerly observed as attaching to it at Grosmont, near Whitby.

From the details just given it will be seen that, although the quantity of ironstone in the Main Cleveland seam is practically inexhaustible, the portion which, in recent years, has yielded such immense quantities of rich mineral, as far as we can at present judge, occupies comparatively a very limited area. Commencing at Swainby, near Osmotherley, which is the most western point where the bed is worked, its thickness is not much above three feet, and the per centage of iron under 28. It improves gradually in a north-eastern direction past Kildale, where a working was attempted, and abandoned, by the writer's firm. It is not until we reach Codhill, 13 miles from Osmotherley, that the seam is considered worth extracting; and a line from this point to Rockcliffe, on the coast, a distance of twelve miles, will probably be found as forming the southern boundary of the best stone, so that after making the necessary allowance for denudation, 20 to 30 square miles may be assumed as the extent of the area, of which a considerable portion lies at a great depth.

Much more irregular in its features is the so-called Top seam. At Normanby and Eston little more than its position can be recognised, and throughout the entire field it varies from a few inches to many feet in thickness. In richness of iron it is not less changeable, giving from 20 to 35 per cent. of metal, according to the locality from which the sample may be taken. In the main seam there exists a certain degree of uniformity, even in the change of thickness and richness; but in the Top seam both alternate very frequently in a most unlooked-for manner. On the western side of the district, Ingleby Greenhow is the most northern, and indeed the only place where the Top seam has been wrought in that direction. In the mine there its thickness was 2 feet, and its richness in iron 34·75 per cent. On the other side of the valley it thinned away to a few inches, containing 37·65 per cent. of metal. Near Osmotherley

the seam is several feet thick, and in it a few inches at the top contain 41 per cent. of iron; these are succeeded by 3 feet of stone, with 24·5 per cent. lying upon the top of 10 feet, giving 16·70 per cent. of iron. On the east coast, at Port Mulgrave, Messrs. Palmer formerly worked a small district of the Top seam, 4 to 4½ feet thick, which on analysis gave 30·99 per cent. of iron. In Goadland Dale, Glazedale, Fryup Dale, and Danby Dale, this seam varies from 5 feet to 8 or 9 feet in thickness, and yields from 20 to 25 per cent. of iron. In one case it is as low as 9·33, and in another case as high as 30·11 per cent., but both of these results were from a very limited area. Unless the magnetic ironstone worked at Rosedale Abbey is a portion of this Top seam, about which some doubt has been expressed, all the workings in connection with this bed have been abandoned from the causes just enumerated.

A word or two respecting the mode of extracting the ironstone from the Main Cleveland seam in the northern portion of the field, *i.e.*, near Middlesbrough, will probably not be considered as altogether superfluous. There is a portion of the bed at the top 3 feet thick, over and above the heights of the seam formerly given, and separated by a parting from the remainder of the bed, which parting varies from being a mere point of separation to a thickness of 6 or 7 inches. When it attains this latter thickness, or even less, its contents are so impregnated with bisulphide of iron as to give 28 per cent. of sulphur. This band being easily detached from the ironstone, was applied in the chemical works at Washington as a substitute for ordinary pyrites, and continued to be so used until a manufactory at Middlesbrough was able to consume all the produce of the district on the spot. An analysis of the 3 feet and of the sulphur band are to be found in the table hereafter given. The 3 feet is left in the workings to form the roof of the mine. The remainder of the seam varies from 8 to 10 feet in height, and, indeed, occasionally reaches 16 feet, or even more. In extracting the stone, headways are driven 9 feet wide and 90 feet apart, from which, at intervals of 30 feet, boards are excavated 15 feet wide. By this system "pillars" are left 90 feet long by 30 feet wide. When the limits of the royalty are reached, or when, from any other cause, it is deemed necessary to work the pillars, they are removed, with something like a loss of 10 per cent. of their contents, so that in a good working, free from faults, the whole of the ironstone, within, perhaps, 7½ per cent., can be brought away.

The following tabulated results of analyses will give a correct idea of

the component parts of the Main Cleveland Ironstone seam, taken from that portion of the district where it is found in the greatest perfection :—

	Normanby, average of Seam worked.	Eston.	Upleatham.
Protoxide of iron	38 06	39·92	37·07
Peroxide of iron	2·60	3 60	4 48
Protoxide of manganese	0 74	0 95	0 00
Alumina	5·92	7·86	12·37
Lime	7·77	7·44	4 67
Magnesia	4·16	3 82	2·69
Potash	0 00	0·27	0·00
Carbonic acid	22·00	22 85	23·46
Silica	10 36	8 76	10 63
Sulphur	0·14	0·11	0·00
Sulphuric acid	0 00	0·00	0 00
Phosphoric acid	1·07	1·86	1 17
Organic	0 00	0 00	0·00
Water	4·45	2 97	3 36
	97 27	100 41	99 90
Metallic iron	31·42	33·62	31 97
Authorities	Clarence Lab.	Dicks. Geo. Survey.	Crowder.

	Skelton.	Skelton.	Normanby 3-feet Roof.	Sulphur Band.
Protoxide of iron	45·60	44·31	33·86	9 97
Peroxide of iron	—	—	·47	—
Protoxide of manganese	·75	—	·96	—
Alumina	8·51	11·66	6 92	8·47
Lime	6 31	4 66	5·82	·49
Magnesia	3 85	2·33	3 84	1·07
Potash	—	—	—	—
Carbonic acid	21·30	27·25 includes water.	25·00	—
Silica	10·54	7·66	15·24	10·94
Sulphur	—	1·04	·40	28 37* 24 82
Sulphuric acid	—	—	—	—
Phosphoric acid	2·92	1·80	1·40	—
Organic	—	—	—	—
Water	—	—	3·69	13·20
	99·78	100·71	97·60	97·33
Metallic iron	35·46	34·43	26 66	—
Authorities	Clarence Lab.	Clarence Lab.	Clarence Lab.	Clarence Lab.

The relationship existing among the earthy constituents of the Cleve-

* Sulphur and iron, as bisulphide of iron ; 28·37 sulphur, 24·32 iron.

land ironstone, it will be seen, varies somewhat in different localities. This is not to be wondered at, for, in fact, the seam itself in the same section is by no means uniform in its composition. A moment's inspection of the furnaces working the ironstone of the district, enables a practised eye to perceive a very marked difference in the general character of the slag compared with that usually seen at iron works. Although it flows hot and fluid, it is extremely stony in its fracture, with scarcely a vestige of a vitreous nature. A very short comparison of the relationship which the earths bear to each other in ores of other parts of the country with those under examination, will explain this. The following may be instanced :—

	Low Moor.	Parkgate.	Butterly.	Brierly.	Stanton.	Cleveland.
Silica	60	44	54	60	50	34
Lime	9	13	11	9	13	27
Magnesia	8	19	9	7	17	14
Alumina	23	24	26	24	20	25
	100	100	100	100	100	100

The following analyses show the composition of slags produced at different works :—

Slag from	Wales. Cyfarthfa.	Wales. Dowlais.	Staffordshire. Dudley.	So. Yorkshire. Low Moor.
Silica	45·00	43·2	38·76	43·5
Alumina	16·5	12·0	14·48	11·0
Lime	27·7	35·2	35·68	33·6
Magnesia	4·5	4·0	6·84	3·6
Protoxide of iron	3·6	4·2	1·41	8·1
Sulphur	1·4	—	·98	·8
Potash	—	—	1·11	—
	98·7	98·6	99·26	100·6
Authorities	..	Berthier.	Dr. Percy.	..

Those from Cyfarthfa and Low Moor were analysed under the writer's eye. In the case of Low Moor the iron was chiefly metallic.

On comparing the composition of the slags from the Welsh, Staffordshire, and South Yorkshire works, just given, with those from the furnaces in Cleveland, the great dissimilarity in constitution will at once be perceived, and a little further examination will show, that with the composition of our ores no mere addition of lime can ever imitate the vitreous slags of those localities just mentioned.

The following analyses illustrate this :—

	Slag from Clarence.	Clarence.	Clarence previous one repeated.	Clarence.	Ormsby.
Silica	30·40	27 80	27·68	27·65	29 92
Alumina	20·72	22·28	22 28	24·69	21·70
Lime	36·88	40·45	40 12	40·00	38·72
Magnesia	4·25	7·21	7 27	8·55	6 10
Protoxide of iron	3·64	·61	·80	·72	·32
Ditto manganese	1·02	trace	·20	·35	·80
Sulphur	1·34	2·00	2 00	1·95	1·61
Potash	·50	—	—	·46	—
Soda	—	—	—	·99	—
Phosphorus	—	trace	—	·26	·07
	98 75	100·35	100 35	100·62	99 24
Authorities	Clarence Lab.	Clarence Lab.	Clarence Lab.	W. Crowder.	Clarence Lab.

There is one circumstance connected with the composition of these slags which may have some interest in a chemical point of view, inasmuch as it may throw some light on a subject not yet very deeply examined, namely, that of the comparative volatile nature of the earths, or of the comparative facility with which they are decomposed and vapourised. In all the analyses hitherto made by the writer, the composition of none of these slags corresponds with the amount of earthy matter introduced into the furnace; thus, in the three specimens of slag from the Clarence furnaces the silica, alumina, lime, and magnesia bear the following average ratio to each other, as expressed in whole numbers:—

Silica.		Alumina.		Lime.		Magnesia.		
30	+	24	+	41	+	5	=	100

After analysing the Normanby ironstone which was used about that time, and adding to its earthy constituents those introduced in the coke and limestone, the slag, by calculation, should have been, as regards the above-named elements, composed of—

Silica.		Alumina.		Lime.		Magnesia.		
29	+	16	+	46	+	9	=	100

The analysis in the School of Mines would, it is true, give a somewhat different result, but one which, nevertheless, does not correspond with actual examination of the slags, even had a similar quality of mineral been in use at Clarence. The Eston stone, smelted with the same kind of coke and limestone, should have given slags containing the earths in the following proportions:—

Silica.		Alumina.		Lime.		Magnesia.		
28	+	18	+	45	+	9	=	100

There escapes, as may be easily seen, from the furnaces on the Tees, &c.,

vast volumes of white vapour, which condense, or partly condense, with great facility. That there is a difference in the readiness with which it does this, may be inferred from the fact, that while large quantities of condensed matter are intercepted in the pipes for leading the gas to the boilers, a great amount travels many yards before it reaches a lofty chimney, from which it escapes as a white cloud, and this cloud goes a long distance in the atmosphere before it is finally dispersed. Nothing short of entire interception of the vapour will enable us to judge whether the discrepancy between calculation and fact can be reconciled. The writer is now engaged in arranging a steam pump which, by continued exhaustion through water or otherwise, will effect, no doubt, complete condensation of each of the component parts of this fume, when some light may be thrown upon the nature of the volatilized portions of the minerals used in our blast furnaces.

This fine dust has been examined at the Clarence Laboratory, and although the analysis proves nothing, having been taken at one place only in the connecting pipes, a statement of its composition may not be devoid of interest. It gave—

Silica and sand	34·82
Alumina	16·00
Lime	12·15
Magnesia	·57
Peroxide of iron	8·20
Oxide of zinc	4·60
Sulphuric acid	8·80
Potash	·40
Soda	6·85
Chlorine	1·56
Water	5 60
	99·55

Clarence Laboratory.

From a more recent examination of the fume, taken at different distances from its point of exit from the furnace, the varying proportion of lime would indicate that this earth maintains the condition of vapour longer than the other constituents of the condensed matter :—

At 30 yards from the point of exit the dust contained				9·0 per cent of lime.	
At 60	Do	Do.	Do.	12·5	Do.
At 130	Do.	Do.	Do.	14·0	Do.

In order to supply that deficiency in silica noticed as existing in the

slags, and which might possibly affect the quality of the iron itself, there was added to the charge at the Clarence Works a silicious mud, and subsequently at Eston, freestone, by Messrs. Bolckow and Vaughan. A vitreous slag resulted, but no very marked improvement being noticed in the iron, the addition was discontinued.

TEMPERATURE OF BLAST.

The uniform practice in the whole district is to blow the furnaces with heated air. Sufficient data are not possessed to enable us to speak with any degree of certainty respecting the application of cold blast; but as far as actual experience goes, it is in favour of the idea that the lias ironstone would prove very intractable under that mode of smelting. In the year 1841, from some reason or another, cold air was used during four months at Birtley. The furnaces only ran 42 tons per week of white iron, produced by a consumption of 3½ tons of coke to the ton. At Clarence an attempt recently was made to operate on the Cleveland ore in the same way; twice the quantity of coke was used which is required when making foundry iron, and only white pig was obtained.

A more elevated temperature being wished for than is easily commanded by means of heated iron pipes, various experiments were tried at the Clarence Works, and ultimately Cowper's stoves were introduced. In these, by an alternate system of heating a mass of brickwork in closed vessels of iron, and passing the air through the same, a temperature of 1000° F. and upwards, in the blast was obtained. The condensation, however of the furnace fume, the apparatus being heated by the waste gases, so interfered with the efficiency of the apparatus that the system was modified. Previous experiments were then continued, in which an arrangement of clay pipes, iron pipes, and forge cinders was made to replace the bricks. This was a great improvement, the temperature of the air was increased up to 1200° F., and the tubular arrangement permitted the apparatus to be more easily cleaned. In time, however, the same inconvenience from the condensed fume interrupted the value of the results, and the plan was abandoned. At no time was the high temperature maintained with that regularity upon which success alone depends. Enough, however, was ascertained to give encouragement to the idea that a steady increase of 500° or 600° in the blast would have been serviceable.

To avoid the inconvenience of the flue dust, Messrs. Cochrane erected

large gas generators to obtain carburretted hydrogen and carbonic oxide from the imperfect combustion of coal. The writer is unable to say what have been the advantages attending this mode of operating. The loss of heat from such a plan of applying coal and other sources of expense will probably be a serious impediment to the full measure of usefulness of the system. At the Wylam and Wear Iron Works the writer has introduced an arrangement by which the blast is heated by means of the waste heat from the coke ovens.

SHAPE OF THE BLAST FURNACES.

In shape, our blast furnaces present no novelty worthy of notice. The width of the boshes varies from 14 to 18 feet, and the height from 42 to 50 or 55 feet, in one case 75 feet having been reached with beneficial results. An average proportion will, probably, be three diameters of the boshes to the entire height, but no great importance can be attached to this ratio, inasmuch as the furnaces continue to work well long after the destruction of the lining has greatly altered the dimensions just given. One attempt has been made here to employ Alger's furnace, in which the circular horizontal section is replaced by one of an elliptical character. In this form the iron is tapped, and the slag allowed to run from the back as well as from the front of the furnace. At the Stockton Iron Works, where the system has been tried, the major axis of the ellipse is 12 feet, and the minor 5½ feet in the hearth—the higher part of the fur-

Note to Temperature of Blast.—Since this part was printed Messrs. Cochrane have informed the author that they experience no difficulty in maintaining a temperature of 1150° in Cowper's Stoves, and that they thereby effect an economy of five cwt. of coke in the blast furnace on the ton of iron, as compared with the furnaces using air heated in the ordinary way. Messrs. C. also state that in any future furnaces they propose using this form of apparatus.

tion of a furnace is from 200 to 220 tons weekly, although more than this quantity has been frequently obtained.

QUALITY OF IRON FROM CLEVELAND IRONSTONE.

Notwithstanding the composition of the slags already spoken of, the

furnaces drive with great ease and rapidity— the cinder flowing, when the make is foundry iron, perfectly liquid, and of an intense white heat.

For foundry purposes the Cleveland iron was at first objected to from its chilling quickly in the "ladle," when compared with the makes of Scotland, and producing more "scum" than the metal from that country.

The writer had this scum analysed at the Clarence Works, and found it to consist of—

Silicate of iron	42·10
Protoxide of iron	8·32
Iron	42·02
Carbon	1·93
Protoxide of manganese	2·82
Lime	·49
Magnesia	·10
Phosphorus	1·11
Sulphur	·23
Titanic acid	·88
	100·00

The furnaces of this district have little tendency to produce what is technically known as "glazy iron." Some years ago one of the Clarence furnaces, however, did run a quantity of this kind of metal. Two samples of it were analysed, and their composition was ascertained to be as follows:—

	No. 1 Pig.	No. 1 Pig.
Iron	88·18	90·70
Carbon combined	·79	·71
Ditto uncombined	2·59	2·68
Silicon	5·13	5·13
Manganese	·77	·56
Sulphur	·17	·23
Phosphorus	1·12	1·12
Titanium	·26	·18
Calcium	·22	·20
Magnesium	·06	·03
	99·29	101·54

Authority .. .. Carence Laboratory.

Silicon evidently constitutes the chief difference between the two samples given above and the iron usually produced in the neighbourhood.

The composition of fifteen samples of ordinary iron smelted from the Cleveland lias stone is exhibited in the annexed table of analyses. These

examinations, with two exceptions by Mr. Crowder, have all been performed in the Clarence Laboratory.

	Clarence. No. 1 Pig.	Clarence. No. 1 Pig.	Clarence. No. 1 Pig.	Tees. No. 1 Pig.	Cleveland. No. 1 Pig.	So. Bank. No. 1 Pig.
Iron	93·030	92·68	94·13	92·40	92·43	92·57
Carbon combined ...	·480	·78	·93	·44	·32	·47
Do. uncombined	2·830	2·43	2·34	2·78	3·43	2·89
Silicon	2·310	2·72	2·57	3·71	1·70	1·76
Manganese	·576	tr.	·31	·49	·30	·44
Aluminium	tr.	—	—	—	—	—
Calcium	—	—	—	—	·05	·03
Magnesium	—	—	—	—	·01	·01
Titanium	—	—	—	·20	·56	·51
Sulphur	·040	·25	tr.	·16	·13	·12
Phosphorus	·300	·30	·30	1·20	1·24	1·29
	99·566	99·16	100·58	101·31	100·17	100·09

	Clarence. No. 3 Pig.	Clarence. No. 3 Pig.	Clarence. No. 3 Pig.	Clarence. No. 4 Pig.	Clarence. No. 4 Pig.	Tees. No. 4 Pig.
Iron	93·96	93·66	92·35	94·64	91·55	93·84
Carbon combined ...	·43	·28	1·24	·26	1·26	·22
Do. uncombined	2·67	3·13	·68	2·45	1·06	2·72
Silicon	2·70	·88	1·80	1·87	1·84	2·16
Manganese	·52	·37	·81	·93	1·06	·50
Aluminium	—	—	·36	—	·27	—
Calcium	—	·30	·93	—	·44	·45
Magnesium	—	·02	·24	—	·15	tr.
Titanium	·25	·14	—	—	—	·09
Sulphur	·10	·17	·04	tr.	·80	·26
Phosphorus	·72	1·23	1·55	1·00	1·57	·83
	101·35	100·18	100·00 Crowder.	101·15	100·00 Crowder.	101·07

	Clarence. Mottled.	Clarence. White.	Clarence. White.
Iron	93·59	97·30	97·036
Carbon combined ...	·85	·90	·788
Do. uncombined ...	2·70	1·06	
Silicon	·56	·11	·400
Manganese	·79	·11	—
Aluminium	—	—	—
Calcium	·26	·15	—
Magnesia	·07	·06	—
Titanium	—	—	—
Sulphur	·35	·96	·342
Phosphorus	1·05	·26	1·434
	100·22	100·91	100·00

From the following summary of some of the experiments on iron, undertaken by the War Department, an idea of the important question of relative strength may be gained. It is only fair to add that these trials

were made soon after the works on the Tees commenced operations, since which time the qualities of the ore and its mode of treatment are better understood.

Kind of Iron.	Qual.	S.G.	Breaking Weight, tensile test. lbs.	Breaking Weight, transverse. lbs.	Deflection.	Breaking Weight, torsion. lbs.	Angle torsion.	Force required for crushing. lbs.
Whitehaven—Hematite Foundry	1	7·097	14233	4644	·161	3724	7·2	52136
	3	7·214	17751	5105	·120	4182	5·8	82265
	4	7·196	17566	6100	·152	4977	4·9	82583
Butterly—clay ironstone	1	7·141	23388	7106	·145	7346	9·3	88488
	2	7·078	18970	6077	·128	6011	7·5	74743
	3	7·126	23265	6692	·130	6940	7·5	91663
Ystalyfera—clay do. anthracite ...	1	7·165	25172	7848	·163	6704	12·2	87457
	2	7·157	26758	7944	·196	6176	9·6	90874
	3	7·150	24533	7228	·166	5719	8·8	88772
Blenavon		7·163	26766	7947	·182	5487	6·1	105202
Blenavon cold blast ...	1	7·137	25456	7493	·171	5034	9·	91897
	3	7·158	23906	7600	·191	5674	10·2	87358
Cleveland—Stockton Furnaces... ...	1	7·148	25810	7159	·136	5872	4·2	99526
	2	7·135	22271	6932	·134	6305	5·7	87063

From these figures it would appear that the iron from this northern locality stands very well even when contrasted with some of the best brands of the kingdom. A large founder at Middlesbrough states the Cleveland iron to be strong in the lower classes, viz., Nos. 3 and 4. A bar 2 in. × 1 in., with bearings 3 feet apart, carried 27 to 30 cwts. Under tension, bars having a sectional area of one centimetre, bore 35 cwts. before fracture occurred. In melting for the foundry, the same authority states 2 to 2½ per cent. to be the loss on pig iron obtained from Cleveland stone.

At the Clarence Works the following experiments were undertaken with bars to ascertain the breaking weights. The bars were 2 in. × 1 in., and supported on bearings three feet apart:—

Quality of No.	Deflection.	Breaking Weight. Cwts.	Qrs.	Lbs.
No. 1	·65 in.	29	2	22
2	·62 „	28	2	22
3	·60 „	30	0	22
4	·56 „	30	0	22
5	·59 „	27	2	22
6	·60 „	29	0	22
7	·62 „	29	0	22
8	·55 „	28	2	22
9	·52 „	28	2	22
10	·55 „	29	2	22
Average ...	·586	29	0	22

Quality of iron in bar.		No. 4 Deflection.		Breaking Weight. Cwts.	Qrs.	Lbs.	
No. 4 iron	10 others...	·609 in.	......	28	0	5	
4 „	10 „ ...	·593 „	......	28	2	27	run from No. 2 pig.
4 „	10 „ ...	·593 „	......	28	2	12	run from No. 3 pig.
	Mottled.						
No. 1 ...	... ...	·058 „	......	31	2	22	
2 ...	... ...	·054 „	......	29	2	22	
3 ...	... ...	·048 „	......	27	2	22	
4 ...	... ...	·041 „	......	26	2	22	
5 ...	... ...	·046 „	......	27	2	22	
6 ...	... ...	·048 „	......	29	2	22	
	Average ...	·049		28	3	12	

EFFECT OF MANGANESE IN THE BLAST FURNACE.

The experiments of Mons. Caron in ascertaining the effect of manganese on pig iron, which he found sensibly to reduce the amount of sulphur, led the writer to try the effect of it in the Clarence furnaces. The results, in a chemical point of view, are not devoid of interest, inasmuch as they afford some indication of the behaviour of this metal under the treatment of an iron furnace. The ore itself was poor in manganese; the composition was as follows :—

Silica	25·00
Peroxide of iron	24·30
Peroxide of manganese	37·19
Oxide of do.	8·51
Loss by heat	5·00
	100·00

The iron produced gave by analysis for different qualities as follows :—

	No. 1 Pig.	No. 2 Pig.	No. 3. Pig.
Carbon	2·94	2·90	3·30
Silica	2·50	3·53	3·80
Manganese	1·75	2·31	2·45
Sulphur	·292	·247	·254
Phosphorus	·416	·860	·867

As far as the two last mentioned elements are concerned, the addition of manganese in the furnace does not appear to have effected much change, but it is quite possible that the increase of this metal may, when the iron is remelted for the founder, remove a portion of the sulphur. Mons. Caron ascertained that this change occurred when manganese was fused with iron containing sulphur. Want of opportunity has prevented this examination from being pursued.

The slag was of the following composition while the furnace was working with the manganese ore:—

Silica	29·25
Alumina	19·25
Lime	38·25
Magnesia	·60
Protoxide of iron...	1·04
Do. manganese	8·76
Sulphur	2·16
Oxide titanium	·75
	100·06

By calculation it was ascertained that for 100 parts of metallic manganese introduced into the furnace,

There came out in the iron	9·5
In the slag...	87·6
Leaving unaccounted for	2·9
	100·0

These figures require a little modication, difficult to define, arising from a varying amount of manganese being found both in the iron and in the slag of furnaces using Cleveland ironstone alone.

USE OF THE WASTE GASES.

The waste gases are employed for raising steam and heating the blast, but on the use of this mode of economising coal there still exists a considerable diversity of opinion. Extra consumption of high-priced coke and irregularity of working in the furnaces themselves, is not in every case a commercial equivalent for the inferior small coal saved, and labour in firing boilers, &c., avoided. In the writer's opinion there is some force in the objection; at the same time his own experience, after incurring great expense in the necessary gas apparatus, leads him to persevere, in the hope that even the objections he admits to exist, will vanish with the knowledge which time and patience alone can secure.

It is, however, reasonable to suppose, as far as a mere question of fuel is concerned, that the combustion of the carbonic oxide at the top of a furnace must heat the materials to a greater or less extent, and whatever this may amount to will be a saving *pro tanto* lower down the furnace.

To ascertain, if possible, what amount of heat was really imparted to the contents of a blast furnace by the combustion of the carbonic oxide at the top, an examination has been made within the last few days of two

furnaces at the Clarence Works, one open-topped, and the other close-topped. At the former the gases were burnt, and from the latter they were conducted away unconsumed. Both furnaces were of the same construction, and both were using materials similar in quantity and quality, and producing the same kind of iron. In both instances the temperature was taken 8 feet below the charging plates.

At the close-topped furnace the following results were obtained:—

	H. M.		Deg. F.	
Time of observation...	... 2·25	Temperature ...	890	
	2·31	... ...	1040	
	2·40	... ...	1040	
	3· 5	... ...	1107	
	3·50	... ...	1240	
Put on 56 cwts. materials ...	3·20	... ...	1240	
	3·30	... ...	1299	Mean ... 1121 F.

Day following.

	H. M.	H. M.	H. M.		
Time of observation ...	3·20	... 3·20	... 3·45		
Temperature	1175	... 1227	... 1275	......	Mean temp. 1226
Put on 76 cwts. materials	...	...	... ...	......	Temp. ... 1240

Day succeeding.

	H. M.	H. M.	H. M.	H. M.		
Time of observation ...	3·20	... 3·30	... 3·35	... 3·55		
Temperature	1305	... 1282	... 1282	... 1415	Mean	... 1321
Put on 30 cwts. materials, temperature ...	4·5	... —	... —	... —	Mean	... 1438
Ditto 74 ditto ...	4·20	... —	... —	... —	Mean	... 1438

The mean of these observations indicates 1200° as being the probable temperature of a close-topped furnace, 8 feet below the charging plates.

An attempt was then made to ascertain the temperature of the gases at a point 8 feet below the charging plates of the open-topped furnace. One observation only was obtained, which indicated 1692°.

In all these experiments the temperature was ascertained by heating a cylinder of copper of a given size, and ascertaining the effect it had on an accurately-measured quantity of water. In the case of the open-topped furnace, the temperature was so high that this apparatus became unmanageable; the copper getting so hot that the water was thrown violently out of the vessel containing it. Looking at the single observation obtained and subsequent appearances, the temperature of the gases in an open-topped furnace will probably be about 1800°, or 600° above that of the close-topped furnace, the datum line in each case being as before stated 8 feet below the charging plates.

TEMPERATURE OF ESCAPING GASES FROM FURNACES.

Scheerer gives 572° F. as the temperature of the upper zone of a blast furnace. The writer recently made the following examination of the temperatures of different furnaces working with close tops.

Clarence No. 5 furnace, 48 feet high, making No. 4 iron.

	H. M.			
Full	2·0	temperature of	escaping gases,	558° F.
	2·25	ditto	ditto	850°
Put on 75 cwts. materials ...	2·35	ditto	ditto	580°

Same furnace making Nos. 2 and 3 iron.

	H. M.			
Full	2·0	temperature of	escaping gases,	710°
	2·10	ditto	ditto	840°
	2·20	ditto	ditto	940°
Put on 25 cwts. materials ...	2·30	ditto	ditto	710°

Walker No. 4 furnace, 42 feet high, making No. 4 iron.

	H. M.			
Full	2·0	temperature of	escaping gases,	690°
	2·10	ditto	ditto	800°
Introduced 33 cwts. materials	2·20	ditto	ditto	670°

Middlesbrough No. 2 furnace, 42 feet high, making white iron.

	H. M.			
Full	2·0	temperature of	escaping gases,	519°
	2·20	ditto	ditto	960°
Put on 90 cwts. materials ...	2·30	ditto	ditto	469°

The mean temperatures will be as follow :—

Clarence, making No. 4 iron	710°
Ditto, making No. 2 iron	825°
The mean temperature of the tube conveying the gas from four furnaces was	808°
Walker, making No. 4 iron	740°
Middlesbrough, making white iron	715°

The object of these figures is to show that taking Scheerer's statement as our guide the whole of the furnaces alluded to are working to a loss.

It is obvious that there is an escape of heat capable of preparing an additional quantity of material for treatment in the reducing and fusing zones of the furnace. The obvious method of making this heat available is by increasing the height of the furnace itself. This, however, has its limit, varying probably with the nature and size of the materials used. If, for example, the fuel is easily crushed, or the "mine" is small or easily rendered so, then the altitude of the column containing it must not be

above that which will permit the blast to enter freely and preserve, as far as possible, an equal temperature over every horizontal section or zone of the materials.

It is more than probable that the limits of extreme height have been already reached by experience in other localities, the ironmaster there being guided by the peculiar characteristics of his own minerals.

The iron furnaces in Cleveland work under a totally different set of circumstances to those of Staffordshire, for instance, where the coke is friable and the mine small. Our coke is endowed with great hardness and capability of resisting pressure, and our ironstone, worked in great blocks, is sufficiently large to permit a free passage of air through a much higher column than otherwise would be the case.

Messrs. Bolckow and Vaughan have actually put this to the test of practical proof by erecting a furnace seventy-five feet high. Upon one occasion, in making No. 4 iron, the gases were escaping at a temperature of 467° just after charging, and 665° when ready for its charge, or a mean of 517°; the reduction of something like 200°, being due no doubt to the increased burden which this higher furnace was actually carrying.

Economy of fuel in the blast furnace is of twofold importance—first, from its direct action in reducing the cost of making iron; and secondly, as the superiority and quality possessed by charcoal iron over that smelted by pit coal, consists, in all probability, in the greater amount of impurity contained in the latter description of fuel, it obviously becomes a matter of consideration to employ as small a quantity of coke as possible, so as to diminish the weight of foreign matter introduced into the furnace. Hence any system interfering with these conditions requires close and careful watching on the part of the ironmaster.

MAGNETIC IRONSTONE OF ROSEDALE ABBEY.

Hitherto our observations have been confined chiefly to describing the natural and metallurgical features of the Main bed of ironstone in Cleveland, but as there are some matters of interest connected with the Top seam, a short notice of it here may not be out of place.

This seam of the Lias formation (which is either the Top seam or very near it in geological position), has been wrought in two or three places, but by far the most important workings are the mines at Rosedale Abbey. The samples, Nos. 1 and 2, are analyses of the Rosedale Abbey ironstone. No. 4 is the Top seam from Ingleby

	No. 1. Blackstone.	No. 2. Bluestone.	No. 3. Ingleby.
		33·85 Fe O	41·14 Fe O
Oxide of iron	64·90	32·67 $Fe^2 O^3$	7·07 $Fe^2 O^3$
Oxide of manganese	—	·69	·94
Alumina	9·25	3·15	4·71
Lime	3·53	2·86	3·32
Magnesia	·99	—	3·34
Potash	—	trace	·20
Carbonic acid	—	10·36	26·00
Silica	5·70	6·95	7·37
Loss by heat	16·15	1·59	—
Sulphur	—	·03	·08
Phosphoric acid	—	1·41	1·36
Carbonaceous	—	·84	·38
Water	—	3·76	3·86
	100·52	98·16	99·77
Authorities	W. Crowder.	J. Pattinson.	Clarence Laboratory.
Metallic iron	45·43	49·20	36·95

The Rosedale stone is chiefly smelted at Ferry Hill furnaces, and to some extent as a mixture at other works. In quality the iron is much like that which is obtained from the main beds of ironstone.

The Ingleby stone is a portion of the Top seam, and, being thin and expensive to work, is now abandoned. A few hundred tons were smelted without admixture at the Clarence Works. The content of iron was verified as being superior to the ordinary Cleveland Main seam, but the metal in quality did not differ from the usual make of the district.

WEARDALE ORES.

The Weardale ores, from the quality of iron produced by their use, require some separate notice. They are found in the veins of the mountain limestone, either as sparry or spathose carbonates, or as hydrated peroxides; the latter, no doubt, resulting from the joint effects of atmospheric and aqueous action on the former. The following information, communicated by Mr. Attwood, shows the composition of both varieties:—

	Spathose. Dr. Percy.	Hydrated Peroxide. Dr. Percy.	
Protoxide of iron	49·77	—	
Peroxide of iron	·81	71·11	
Protoxide of manganese	1·93	6·60	
Lime	3·96	·56	
Magnesia	2·83	1·90	
Alumina	—	·40	
Carbonic acid	37·20	·13	
Sulphur	0·04	—	
Phosphoric acid	trace	·22	
Water	0·30	12·40	
Insoluble residue	3·12	6·32	{ Si 4·0 Al 1·97
Protoxide copper	—	trace	
	99·96	99·64	
Metallic iron	38·95	49·78	

Dr. Richardson gives the following as the composition of a specimen of Weardale spathose ore:—

Iron	44·73
Lime and magnesia	3·95
Silica	·95
Loss by heat	35·50

The character of the iron produced from the above ores is of a marked kind, highly crystalline, and affording bar iron of a very excellent quality. Recently Mr. Attwood has succeeded, he states, by a plan of his own, in obtaining very good steel from the iron.

The composition of a description of iron coming so near in its properties to that of charcoal iron, as it does, is of sufficient interest to justify attention being drawn to it. The following table shows analyses of both foreign and Weardale iron:—

	No. 1. German. Spiegel Eisen.	No. 2. German. Spiegel Eisen.	No. 3. Swedish.	No. 4. Weardale.	No. 5. Weardale.	No. 6 Weardale. White Spiegel.
Iron ...	82·11 ...	98·655 ...	95·27 ...	93·01 ...	99·510 ...	96·775
Carbon ...	4·77 ...	·210 ...	4·02 ...	4·10 ...	·065 ...	2·092
Silicon ...	·82 ...	1·062 ...	·08 ...	·23 ...	·140 ...	·882
Manganese	11·12 ...	— ...	·10 ...	2·37 ...	— ...	·021
Sulphur ...	·74 ...	trace ...	·30 ...	·21 ...	— ...	·229
Phosphorus	·13 ...	trace ...	·05 ...	·07 ...	trace ...	—
Copper ...	·31 ...	— ...	— ...	·01 ...	— ...	—
	100·00	99·927	99·82	100·00	99·715	99·999
Authorities ..	Dr. Percy.	Mitchell and Richard.	Dr. Percy.	Dr. Percy.	Mitchell and Richard.	Washington Laboratory, by Mons Brivet.

Dr. Percy afterwards having reason to think the proportion of sulphur, as given in his analysis, was too high, repeated the examination, and found it only ·03 per cent. in Weardale spiegel eisen. The slag from the furnace where the specimen No. 5 was made contained:—

Silica	36·80
Alumina, little oxides of iron and of manganese	13·80
Lime	46·00
Magnesia	2·54
Soda and potash, estimated as the difference	·86
	100·00

The coke used at the Weardale Company's furnaces is that from the bottom of our coal series, and which, as a rule here, as in some other coal-fields, appears the best adapted for iron smelting, owing no doubt to freedom from sulphur. The subject is of interest, as showing that the results obtained by the use of charcoal abroad, can be very closely imitated when suitable ores, and mineral coal of great purity is the fuel employed.

CUMBERLAND HEMATITE.

The rich hematites of the Whitehaven district approach in some cases to nearly a pure peroxide of iron.

The following indicates their composition:—

	Cleator.	Cleator.
Peroxide of iron	90·58	95·16
Protoxide of manganese	·10	·24
Silica	7·05	5·66
Alumina	1·43	·06
Lime	·71	·07
Magnesia	·06	—
Sulphur	·03	trace
Phosphoric acid	trace	trace
	99·96	101·19
Authority	School of Mines.	
Metallic iron	63·25	66·61

The following analysis shows the composition of iron from the Cleator furnaces—

Iron	93·94
Carbon	4·18
Silicon	1·92
Manganese	·02
Calcium	·12
Magnesium	·06
Sulphur	·05
Phosphorus	·08
	100·37
Authority	Clarence Laboratory.

This ore and that from Ulverstone are brought, to some extent, to the east coast for admixture with the Cleveland stone.

IRONSTONES FROM REDESDALE AND HARESHAW (MOUNTAIN LIMESTONE), AND FROM CONSETT, NEAR SHOTLEY BRIDGE (COAL-MEASURES).

These ironstones having been incidentally mentioned, the following analyses by Dr. Richardson, may be of interest:—

	Redesdale.	Hareshaw.	Consett, Shotley Bridge.
Iron	34·86	36·51	36·68
Lime and Magnesia	9·00	11·90	4·65
Clay	14·00	7·15	15·05
Loss by heat	31·02	34·07	31·91

In each case, no doubt, the stone was a perfectly clean sample, quite

free from adhering shale, which will account for the difference of metal between the analyses and the actual yield in the furnace, as formerly stated.

STATISTICS OF THE PIG IRON MANUFACTURE IN CONNECTION WITH THE NEWCASTLE AND DURHAM COAL-FIELD.

The following figures, extracted from the statistical returns of the Geological Survey, afford probably the readiest mode of imparting a correct idea of the extent and rate of development of the iron mines now under consideration.

In September, 1850, the first ton of stone was worked from Eston Hill for trial at Witton Park Works. Previous to this the valley of the Esk, and, to a small extent, the coast, furnished the produce of the Lias beds. Subsequently the quantity raised on the coast was increased a little, in consequence of the seam near Skinningrove being recognized as containing more iron.

	Esk Valley. Tons.	Coast. Tons.	Cleveland Hills. Tons.	Total. Tons.
1855	55,000	50,000	865,300	970,300
1856	48,000	57,164	1,141,448	1,246,612
1857	Not properly separated after this, but most of the increase may be set down as being the produce of the Cleveland Hills.			1,414,155
1858				1,367,395
1859				1,520,342
1860				1,471,319
1861				1,242,514*
1862	25,000	98,900	1,566,066	1,689,966

CUMBERLAND ORE.

	Smelted at Newcastle or Middlesbrough.	Smelted in Cumberland.	Exported to other Places.	Total. Tons.
1854	46,785	24,000 estimated	261,257	332,042
1855	37,192	24,106	139,490	200,788
1856	41,450	39,617	168,080	278,147
1857	44,489	56,511	222,812	323,812
1858	57,040	67,248	207,254	331,542
1859	77,200	79,152	243,954	400,306
1860	81,240	128,149	257,462	466,851
1861	65,555	117,654	288,885	472,094
1862	55,838	119,285	357,997	533,120

	Weardale. Brown Hematites and Carbonates.	Newcastle. Claystone.	Cumberland. Alston.
1858	—	1,084	17,094
1859	—	—	1,871
1860	—	—	—
†1861	91,000	—	—
1862	124,750	—	820

* The Government Returns are 111,258 tons short of the actual weight this year.
† The Government Returns are incorrect, only giving 10,750 tons per 1861.

A very large quantity of hematite is obtained from the neighbourhood of Ulverstone, a portion of which is smelted with coke from the Durham Coal-field, while some of the ore itself is brought to mix with the Cleveland ironstone. The following figures indicate the importance of the iron trade of Ulverstone:—

	Carried to Newcastle or Middlesbrough.	Smelted at Ulverstone.	Exported to other Places.	Total. Tons.
1861	11,838	118,759	388,583	519,180
1862	3,548	167,634	388,209	559,391

The following statement gives at one view the number of furnaces on the east coast, existing previous to the recent extension of the iron trade in connection with the Cleveland ironstone worked from the neighbourhood of Middlesbrough, with other particulars of interest connected with its present condition and future prospects:—

Name of Work.	Owners.	Furnaces previous to A.D. 1850.	Furnaces existing 1st Sept., 1863.	Building or projected 1st Sept., 1863.	Furnaces in Blast 1st Sept., 1863.
Lemington	Tyne Iron Co.	2	2	—	1
Birtley	Birtley Iron Co.	2	3	—	3
Wylam	Bell Brothers	1	1	—	1
Walker	Losh, Wilson, & Bell	2	5	—	2
Redesdale	Redesdale Iron Co.	2	dismantled	—	0
Hareshaw	Hareshaw Iron Co.	3	dismantled	—	0
Consett	Derwent Iron Co.	14	14	—	6
Towlaw and Stanhope	Weardale Iron Co.	6	6	—	4
Bedlington	Longridge & Co.	2	2	—	0
Witton Park	Bolckow & Vaughan	4	4	—	4
Middlesbrough	Bolckow & Vaughan	—	8	—	8
Eston	Bolckow & Vaughan	—	9	—	9
Clarence	Bell Brothers	—	6	2	5
Tees	Gilkes, Wilson, & Co.	—	5	—	4
Ormesby	Cochrane & Co.	—	4	—	4
Claylane	Elwin, Malcolm, & Co.	—	3	3	3
South Bank	Elwin, Malcolm, & Co.	—	3	3	3
Stockton	Holdsworth & Co.	—	3	—	3
Norton	Warner, Lucas, & Barrett	—	3	—	3
Tees Side	Hopkins & Co.	—	2	—	2
Thornaby	Whitwell & Co.	—	3	—	3
Normanby	Jones, Dunning, & Co.	—	2	—	2
South Durham	South Durham Iron Co.	—	3	—	3
Felling, River Tyne	Pattinson & Co. & Bell Brs.	—	2	—	0
Jarrow, ditto	Palmer & Co.	—	4	—	3
Wallsend, ditto	Palmer & Co.	—	2	—	0
Bradley	Richardson & Co.	—	4	—	0
Washington	Washington Chemical Co.	—	1	—	0
Wear	Bells, Hawks, & Co.	—	1	—	1
Ferry Hill	James Morrison	—	3	—	3
Seaham	Marchss. of Londonderry	—	2	—	2
Hinderwell	Hinderwell Iron Company	—	1	—	1
Haltwhistle	...	—	1	—	0
Brinkburn	...	—	1	—	0
Beckhole	Bagnall & Co.	—	0	2	0
Newport	B. Samuelson	—	0	3	0
Eskdale Side	...	—	0	2	0
Glazedale End	...	—	0	2	0
		38	108	17	78

The furnaces working hematite ore on the west coast are as follows, taken from the Geological Survey:—

	Furnaces Built.	Furnaces in Blast.
1861—Cumberland	13	8
Lancashire	12	10
1862—Cumberland	13	7
Lancashire	14	11

According to the same authority, the following figures embrace an account of the production of pig iron from the furnaces alluded to in this paper:—

	1860. Tons.	1861. Tons.	1862. Tons.
Northumberland, using chiefly Cleveland stone	69,093 ...	73,260 ...	46,586
Durham, using chiefly Cleveland stone	340,921 ...	312,030 ...	337,218
North Riding of Yorkshire (Cleveland) ...	248,665 ..	234,656 ...	283,398
	658,679	629,946	667,202
Cumberland	87,950 ...	55,165 ...	103,455
Lancashire	81,250 ...	109,377 ...	138,563

MALLEABLE IRON.

Malleable iron was, of course, the description of metal produced by all those bloomeries, mentioned in a previous section of this paper, as is indicated by the heaps of scoriæ found near Roman stations, monastic establishments, and other places. Coming down to more recent times, it is obvious that in a country where, comparatively speaking, there would be a considerable consumption of wrought iron, there was necessarily thrown into the market a corresponding quantity of old or scrap iron. With cheap fuel, and water-power in sufficient quantity to drive small hammers, forges were erected at various suitable localities, such as Swalwell, by Crowley and Co.; Beamish and Lumley, by Hawks; Bedlington and at various other places. It is needless to say the weight of metal so manufactured was small. The next stage in the manufacture of malleable iron was the erection of slitting mills in different places commanding water-power; but when or where first established the writer can scarcely determine. By the kindness of Mr. Stephen Hawks, who has searched through the books at the Gateshead Iron Works, he has ascertained that the slit-rods used there in 1772 appeared to be all brought from London, and probably were manufactured in Wales or the Midland Counties.*

* From information communicated by Mr. S. Hurrell, it would appear that, in all probability, the slit-rods imported to the Gateshead Works were from the mills of a Mr. Reynolds, in Shropshire.

Silt-rods were first made in this neighbourhood from hammered bars; indeed, the writer was informed by the late William Losh, one of the founders of the firm of Losh, Wilson, and Bell, that he erected a slitting-mill near Newcastle, and the iron he used was bars brought from Sweden. This would probably be about the year 1800. Cort patented the rolling of bar iron in the year 1783, and Mr. Stephen Hawks, in an old letter-book of 1799, finds Mr. William Hawks writing, "We will certainly roll the iron to the dimensions you mention," so that probably rolling-mills were introduced in the neighbourhood of Newcastle a very short time after their invention by Cort. In the year 1800, according to information received from Mr. G. C. Atkinson, a small mill was erected at Lemington.

Mr. William Longridge states that his father commenced the Bedlington Works in 1809, the river Blyth supplying the motive power. At that time a plate of 150 to 200lbs. was considered, he observes, something wonderful to produce. It was here that, in 1820, they rolled the first malleable iron rails, an invention of Mr. Birkenshaw.

In 1827, Messrs. Losh, Wilson, and Bell erected, what at that time was considered in the north, a powerful mill, at Walker, capable of rolling 80 to 100 tons of bars a week. Here, as at all the other works, old scrap iron or common Welsh bars, cut up for re-rolling, were the raw materials used. This firm led the way in extending the operation to the "puddling" of pig iron, a process adopted by them in the year 1833.

The rapid progress in Scotland of the manufacture of pig iron from black band by means of the hot blast, and the cheapness of coal on the Tyne, induced Losh, Wilson, and Bell to increase their rolling power. A second mill was erected in 1838, where rails of the largest dimensions, and tyre bars for the wrought-iron wheels, invented by Mr. Losh, were manufactured.

The old house of Hawks and Company soon after added largely to their means of producing wrought iron. In this they were speedily followed by the Derwent Iron Company, who erected immense rolling-mills at Consett, near Shotley Bridge, and increased largely the capabilities of the Bishopwearmouth Iron Works, which they had previously purchased. There would be in the district, previous to 1850, about 300 puddling furnaces, capable of turning out above 150,000 tons of finished iron per annum.

The following list, compiled from actual returns, shows the number of

puddling furnaces now existing in connection with the iron works of the Northumberland and Durham coal-field:—

Works		Firms.	No. of Puddling Furnaces.
Walker ...	Messrs.	Losh, Wilson, & Bell	50
Gateshead ...	„	Hawks, Crawshay, & Sons	33
Consett ...	„	Derwent Iron Company	99
Bishopwearmouth	„	Ditto	81
Birtley ...	„	Birtley Iron Company	6
Bedlington ...	„	Mounsey & Dixon	14
Shotley Bridge	„	Richardson & Co.	27
Hive, Jarrow	„	Elliott & Co.	10
Sunderland ...	„	Tyzack & Co.	7
Britannia ...	„	G. Hopper	16
Jarrow ...	„	Palmer & Co.	30
Tudhoe ...	„	Weardale Iron Company	64
Middlesbrough	„	Bolckow & Vaughan	68
Witton Park	„	Ditto	71
Tees Side ...	„	Hopkins & Co.	55
Albert ..	„	Barmingham & Co	45
Stockton ...	„	Stockton Iron Company	20
		Total...	646

The united power of all these works will be equal to an annual production of 340,000 tons of finished iron, and probably the actual make during the year 1862 may have amounted to 300,000 tons.

In addition to the quantity of iron obtained by the puddling process, a considerable weight, possibly as much as 10,000 tons per annum, is manufactured from old iron imported from various parts of the kingdom.

At first a much stronger opinion existed in favour of refining pig iron, previous to puddling it, than is the case at the present moment. In fact, it may be said that this mode of working has been all but abandoned, as more wasteful than simply puddling the pig iron direct; and indeed one manufacturer of great experience gives, as the result of his observation, that a sectional inch of boiler plate had its breaking weight actually diminished by interposing the process of refining between the pig and the puddled bar. At the new works no refineries are built, and at the older establishments the refineries are all but discontinued.

There is probably less mill and forge cinders used in the manufacture of pig iron from the lias ironstone, either for bar or other purposes, than in any other iron district in the kingdom, and this obviously from the greater abundance and cheapness of ironstone. The extra loss in puddling and the depreciation of quality in the malleable iron is more

than equivalent for any saving in the blast furnace which may be effected by using the forge cinders, into which the greater part of the phosphorus of the pig finds its way. It is also not improbable that the admixture of mill and forge cinders might, with the constitution of the Cleveland ores, be more detrimental to the quality of the bars than is the case in districts smelting other kinds of ironstone. At all events, our bar iron makers seek to avoid any risk of this by its very sparing use.

Some bar iron manufacturers prefer pig having an admixture of a little hematite in the blast furnace, or they seek to secure the advantages resulting from the use of this class of iron by using hematite pig in the puddling furnaces. It is highly probable that some good attends such a course of procedure, as well from the acknowledged excellence of hematite pig as from the advantage that is generally admitted to accrue from using different varieties in the manufacture of malleable iron. The fact, too, that the tendency of the Cleveland iron is towards cold shortness, while that of the hematite is in the opposite direction, increases the probability of the soundness of these views. At the same time, by care in puddling and in the subsequent process, bar iron of a very high class of excellence can be produced from pig obtained from Cleveland ironstone alone.

Messrs. Bolckow and Vaughan have kindly furnished the writer with a series of samples which have been submitted to breaking strains, and the following are the results :—

Experiment.					Tons	Cwts.
No. 1.	Boiler plate [illegible] in. thick sec.	=	1 in. sq.,	breaking weight,	26	10
No. 2.	Do.	,,	1 in.	do.	27	0
No. 3.	Do.	,,	1 in.	do.	25	0
No. 4.	Do.	,,	1 in.	do.	26	0
No. 1.	Bar iron	,,	1 in.	do.	25	0
No. 2.	Do.	,,	1 in.	do.	25	0
No. 3.	Do.	,,	1 in.	do.	25	10
No. 4.	Do.	,,	1 in.	do.	24	10
No. 5.	Do.	,,	1 in.	do.	24	10
No. 6.	Do.	,,	1 in.	do.	24	0
No. 7.	Do.	,,	1 in.	do.	25	0
No. 8.	Do.	,,	1 in.	do.	25	0
No. 9.	Do.	,,	1 in.	do.	25	0
No. 10.	Do.	,,	1 in.	do.	25	0
No. 11.	Do.	,,	1 in.	do.	25	0
No. 12.	Do.	,,	1 in.	do.	25	10
No. 13.	Do. submitted for 60 hours to a strain of 22 tons, during which time the elongation was [illegible] of an inch.					

The quality of both the plates and bars tested in these experiments was No. 3, of extra quality.

Not a bad estimate of the inherent excellence of any pig iron may be formed from the quality of bars it is capable of producing and from the loss of weight incurred in the process of puddling. Within the last few days the writer has received from the manager of one of the largest bar iron works in Scotland, a return of the quantity of Scotch pig iron required to make one ton of puddled bar. He gives 22¼ cwts. of pig for one ton of refined metal; 21¼ cwts. ⅞ths refined and ⅛th pig to a ton of puddled iron, which is equal to 23½ cwts. of pig per ton of puddled iron. When the pig is not refined but puddled direct, 23¼ cwts. are consumed for one ton of puddled iron. These figures, from personal experience of some years, the writer considers to indicate as good a yield as the Scotch iron is capable of affording. From two separate works using pig iron made from Cleveland ironstone the following returns have been furnished; from one, the produce for the whole of 1862, was 22 cwts. 0 qrs. 16 lbs. of pig to the ton of puddled iron, and for the first six months of 1863, it was 22 cwts. 0 qrs. 17 lbs. at the same work. The second establishment gives for the year 1862, 22 cwts. 0 qrs. 16 lbs. of No. 4 iron to the ton of puddle bar. The loss, therefore, on iron produced from Cleveland ironstone is only about 66 per cent. of that when using Scotch iron, and the quality of the former is such that the preliminary process of refining, as has been already stated, is all but entirely dispensed with.

Many of the forges being, under the circumstances just enumerated, of recent construction, embrace all the latest improvements. Very powerful steam hammers forge down the puddled balls so rapidly into blooms or slabs, that two of these are frequently taken simultaneously to the puddling mill and rolled out by "doubling" into a single bar, of dimensions varying with the subsequent destination of the product.

In the puddling furnaces different materials are employed in different localities for protecting the iron bottoms. In some places the plastic hematite from Lancashire is the substance used, in others limestone is preferred. In most cases, however, "bull dog," *i.e.*, calcined mill furnace scoriæ, ground and mixed frequently with a small quantity of red ore, is found a good covering. This substance is capable of resisting the corroding action of puddling pig, which is more rapid than that of refined metal, or a mixture of refined metal and pig.

The qualities of pig iron used in the puddling furnaces vary with circumstances; for a fibrous quality of bar, No. 4 forge pig gives very satisfactory results. A considerable quantity also of white and mottled iron is worked up in our forges.

Finishing mills of great power have been constructed, capable of rolling rails, bars, angle and girder iron of any section, and of the greatest lengths produced in this branch of manufacture. Sheets of all kinds and plates of the largest dimensions, short of the huge masses of iron now applied to our iron-clads, are also turned out, of excellent quality.

Supposing the make of pig iron in the district more immediately connected with the Cleveland ironstone field to have been 667,000 tons, it will probably have been disposed of as follows:—

	Tons.
For foundry purposes in the neighbourhood, say	150,000
For malleable iron	400,000
Exported elsewhere	117,000
Total	667,000

In addition to the ironstone and hematite consumed on the East coast, amounting, as we have already seen, to about ...	1,870,000
There will have been used in pig and bar iron works, and foundries of coal, say	2,900,000
Limestone at the blast furnaces	500,000
Total weight of materials	5,270,000

The capital employed in mines, blast furnaces, and malleable iron works will be from two to three millions sterling.

The annual amount of wages for miners, furnace-men, and workmen engaged in the mills, forges, &c., say ...	£1,750,000
The dues paid to the railways for carriage on minerals and on iron, will not be far short of	500,000

The activity imparted to our local iron trade by the recent discovery of the Cleveland bed of stone near Middlesbrough has few, if any, parallels in the commercial history of the kingdom. Fifty years ago Staffordshire and Wales had reached great eminence as iron-producing districts. Their powers sufficed at that time to supply the chief requirements of our commerce. Gradually, as this demand increased, their means of production extended, until Neilson's discovery of the hot blast enabled the Scotch ironmasters, five-and thirty years ago, to bring their rich blackband into competition with the clay ironstone and hematite ores of England.

Enormous as are the quantities of iron produced by the works of the localities just enumerated, it must be remembered that their present condition was the growth of a considerable period of time. Ten years, on the other hand, sufficed to place the iron trade connected with the Cleveland bed of ore in its present remarkably conspicuous position.

The Middlesbrough ironstone was opened out in the latter part of 1850, and in the year 1860 the following numbers indicate the weight of pig iron smelted in the districts quoted for the sake of comparison :—

	Tons.
Northumberland, Durham, and the North Riding of York ...	658,679
North and South Staffordshire	616,450
South Wales	969,025
Scotland (the whole of)	937,000

The figures are from the Geological Survey.

This rapid rate of increase in our local trade has been maintained without the exercise of any influence of a speculative character. New markets had to be sought, increased sources of consumption had to be organized in our own vicinity, and some prejudices had to be overcome, before the new brands of this additional iron district were fairly accepted as an important contribution to the metallurgical industry of the kingdom. Now that this much has been honestly and completely accomplished, we may fairly look for a great extension of those local branches of manufacture in which iron plays an important part. With our cheap fuel, magnificent and improving harbours, and enormous commerce, it is only reasonable to suppose that rolling mills, engineering establishments, iron ship-building and many other similar undertakings will find a place among us, and assist in maintaining, for the North of England, a very honourable rank in those industrial communities which contribute so largely to the welfare and prosperity of the British empire.

Clarence Iron Works, 26th August, 1863.

ON

THE MANUFACTURE OF STEEL

IN THE NORTHERN DISTRICT.

BY

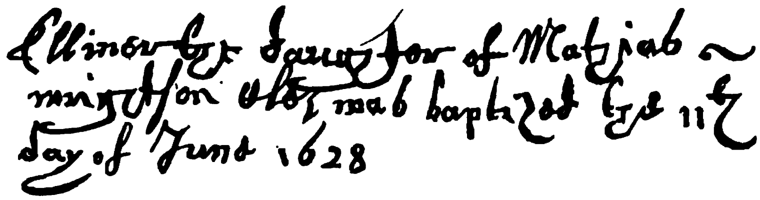
THOMAS SPENCER, M.I.M.E.

THE history of the manufacture of steel in this locality commences at a very early period; for we find that, probably three hundred years ago, a colony of Germans settled at a place on the river Derwent, within a few miles of this town, and, according to tradition, there established this branch of local industry, where they also attained some celebrity as manufacturers of swords and edge tools. The names of these immigrants who, it is stated, took refuge in this country that they might enjoy religious liberty, were Ole, Mohl, Vooz, &c., and some of whose descendants still reside in the village where their ancestors originally settled, the names being now Anglicised to *Oley*, *Mole*, &c. The name of this village is Shotley Bridge, and in the wall of an old two-storey dwelling-house, the original materials of which are hidden under a coat of "rough-cast," there still exists a stone above the doorway with an inscription, in bad German, to the following effect:—

DES.HERREN·SEGEM·MACHET·REICH·OHN·
ALLE·SORG·WAN·DVZVGLEICH·IM·DEINEM
STAND·TREVW·VND·FLEISIG·BIST·VND·
DVEST·WAS·DIR·BEFOHLEN·IST·1691.

of which the following is a free translation, showing that the original importers of the steel manufacture to this district were probably good Lutherans, who had suffered persecution for conscience sake:—"The blessing of the Lord makes rich without care, so long as you are industrious in your vocation and do what is ordered you."

But there is a much earlier record of these German immigrants than the above, the parish register at Ebchester Church containing an entry, of which the following is a fac-simile, traced by the writer, with the kind permission of the Rev. G. Stubbs, the incumbent, by which it will be seen that the name even then had undergone a change:—



This reads—"Elliner, the daughter of Matthias Wrightson Oley, was baptized the 17th day of June, 1628;" and shows also that the grandfather of the child then baptized had probably married into a family of the name of Wrightson, at that time resident in the neighbourhood, as appears by several entries in the parish register of the period, clearly marking a third generation.

In all probability the next works of this nature established in this locality were those of Sir Ambrose Crowley, who is described as an iron-monger, and afterwards Alderman and Lord Mayor of the city of London, and who appears to have commenced a manufactory at Winlaton Mill in the year 1691. The names of Landells and Chambers are mentioned as being in this trade at an early period, after whom came Cookson, Spencer, and others, whose works are carried on at the present time.

The manufacture of steel, as at present carried on in this district, comprises the following descriptions:—Blistered, shear, spring, and cast steel, to produce which the following materials are required:—Iron, carbon in the shape of charcoal, manganese, coal, coke, fire-bricks, and fire-clay—of these, the iron and manganese are imported into the district, the former, for the best qualities of steel, being brought from Sweden. The charcoal, coal, coke, fire-bricks, and fire-clay are produced in almost inexhaustible quantities, and of most excellent quality, in the immediate neighbourhood. A small proportion of the fire-clay, however, is brought from a distance for admixture with that found in the locality.

The mode of manufacture in use here is that known as the cementing or converting process, the furnaces used being large enough to contain from 10 to about 23 tons of material at one time; this material consists of selected iron, and known to the manufacturer as being most suitable for the purpose for which it is ultimately intended. It is placed in the cells of the furnaces with bruised charcoal in alternate strata, the whole being

covered with a vitreous material to effectually exclude the air, and heat is applied for a period of about eight or ten days, according to the degree of carbonization required. The mass is allowed to cool for several days, and the bars are then taken out in the form of blistered steel. The change that has taken place in its structure since it was placed in the converting furnace is very marked; for, instead of being of a fibrous nature, it is now quite of a crystalline character, and it must be reduced or drawn out under rolls or heavy hammers to bring back to it something of its former nature. It is, however, used in the blistered state for many purposes, such as for welding into hammer faces, and for welding to iron for edge tools, and for spades and shovels, although cast steel is now fast superseding its use even for these purposes. Spring steel is made by simply reducing with rolls the blistered bars; and shear steel is made by repeatedly drawing down and welding the blistered bars. This last-mentioned description is also being fast superseded since the introduction of mild welding cast steel.

The most important of what may be termed the secondary processes of this manufacture is that for producing cast steel, and it is (among the old methods of making steel) of the most recent introduction. Cast steel is different from all the other descriptions of steel in its fineness of grain, greater strength, and its homogeneity. The first steel used in this country partaking at all of the nature of this description of steel was the Indian Wootz, which was much prized by users of steel, especially by the makers of dies for coining presses, who, it is said, paid the almost fabulous price of five guineas per pound for it. The discovery of the English method of making cast steel is due to Benjamin Huntsman, of Attercliffe, who appears to have arrived at it by a series of experiments. He was a clockmaker, and desired to improve the quality of steel for clock springs. He was born in some part of Lincolnshire in the year 1704, and although his family are said to have been German, he must have become thoroughly Anglicised, as he was a strict Quaker. In all probability this discovery was made before the year 1760, as it had become public previous to his death, which took place in 1776, at 72 years of age. This process was first introduced into this locality by the late firm of Messrs. Crowley, Millington, and Co., at the beginning of the present century, probably about the year 1810, who were next followed by Messrs. Spencer, of Newburn. Afterwards Messrs. Cookson and Co. erected cast steel melting furnaces at their works at Derwentcote, and within the last few years Messrs. Fulthorpe and Co., of Dunston, commenced this branch of the steel trade. Cast steel is produced by break-

ing the blistered steel into small pieces, and placing the same in crucibles or melting pots, capable of containing 36lbs. to 40lbs. weight each, two of which are placed in each melting furnace. A plentiful supply of coke is now filled into the furnaces, and by the aid of a strong draught of air an intense white heat is obtained, and kept up for three or four hours, according to the nature of the steel required. When it is ascertained that the steel is perfectly melted, the crucibles are taken out, and their contents poured into iron moulds, conveniently placed near, and left to stand until in a cool enough state to be taken out as cast steel ingots. These ingots are afterwards re-heated and hammered, or rolled, or it may be both hammered and rolled, according to the description of article for which it is intended to be used. To produce large ingots, a number of crucibles, containing liquid steel, are brought out of the furnaces, quickly following each other, and a continuous stream is kept flowing into the mould. There is scarcely a limit to the size of ingot that may be made in this way, as was evidenced by the monster block of steel exhibited by Krupp, of Essen, at the International Exhibition in London last year; but great risks are run of getting an unsound ingot, as the least delay in getting out every crucible of steel in perfect order might cause a cessation of the stream, and thus make an unsound casting. In the year 1839, a great improvement was made in cast steel by Josiah Heath, by the introduction of manganese.

Having described the various processes that the several different kinds of steel undergo in its manufacture, it may be useful to notice some of the new methods that have been tried in the neighbourhood.

The method of making steel by the cementing or converting process, as already described, may be called the indirect method, because the object of the process is to deprive, in the first instance, the pig iron of the whole of its carbon, making the product as nearly as possible a pure malleable iron, and afterwards imparting to it again the necessary quantity of carbon to make it into steel. The new methods seem to aim, for the most part, at making steel by a direct process, without depriving the pig iron of the whole of its carbon, and without reducing it into a malleable iron condition. This is effected by extracting a large portion of carbon, but taking care to leave in a sufficient quantity to make steel, the object being to save the great waste of metal attending the puddling of iron, as well as the actual cost of that process. Of these last methods the Uchatius process is one that was extensively experimented on a few years ago at the Newburn Steel Works, and the following is a short description of the manner in which the process was carried on. Pig iron, of a first

class quality, was melted in a reverberatory furnace, and run into a tank filled with cold water, where it was reduced into granules; this granulated cast iron was mixed with pulverized oxide of iron and some alkaline earths, and the whole put into the ordinary steel melting crucibles, and then placed in the furnaces, to which heat was applied in the usual way until it was brought into a fluid state. By this method it was thought that the degrees of hardness of the steel was capable of being regulated by the size of the granules, and by the quantity of oxides used, but after a great number of experiments, at a cost of little under a thousand pounds, on attempting to work it in large quantities, it was found that the product was so uncertain in the qualities necessary to good steel that the process was altogether abandoned. This irregularity of the produce was probably caused by the uncertain quantity of carbon in the pig iron used.

A method of making "puddled steel" has been tried in this locality, but without success. This process was a patented invention of Riepe, a German, and consists in puddling cast iron, in a furnace constructed specially for the purpose, until it is observed to be in the condition of steel. This state is found to exist when a particular form of bubble appears on the face of the metal.

The Bessemer process of making steel has also been introduced into the district, at Tudhoe, near Ferryhill, but with what success the writer is not able to say. The operation, as is generally known, consists of blowing atmospheric air through a mass of melted cast iron until the carbon and the whole of the impurities of the iron are burnt out of it. This process was so ably described by Mr. Bessemer himself, at the meeting of the British Association, at Cheltenham, that it is unnecessary to give a detailed description of it here, but it may be mentioned, that he commenced by extracting only a portion of the carbon, intending to leave a sufficient quantity to produce steel, but the difficulty of adjusting the exact amount finally led him to extract the whole, and afterwards restore the exact quantity requisite by adding a measured amount of highly carbonized cast iron. Experiments in making cast steel from the Taranaki sand from New Zealand, and also from another similar sand from the coast of Italy, have been tried at Newburn, with a result of getting an excellent quality of steel; but, although yielding about 51 per cent. of metal, the cost of its production, without including anything for the value of the sand, was so great, that it would not answer commercially. It may be mentioned that this description of metallic sand appears to possess the remarkable property of not becoming oxidized when kept in a moist

condition; and the writer would call the special attention of chemists and metallurgists to the fact, with the view of arriving at (what would be an invaluable discovery) the production of iron or steel that would not be subject to the destroying action of the oxygen of the atmosphere.

The articles manufactured from steel in this locality are very numerous, amongst which may be mentioned railway axles, tyres and springs, piston rods, motion bars, and files for engineer's use, rings for Blakeley guns, shot, &c., the great bulk of tonnage being railway springs of various kinds—buffing, bearing, and traction, in the laminated form, as well as the volute spring originally made in this country at Newburn, and of which there have been many hundreds of thousands made within the last few years. The rings supplied for guns made in this district have been pronounced by the consumers superior to any others. A firm, in this locality, has been appointed makers of springs for Mr. W. Bridges Adams' patent for the application of circular springs between the tyre and the frame wheel for all kinds of rolling stock on railways, and it is stated that springs applied in this manner effect an increased durability in Staffordshire tyres of 50 per cent. over Krupp's cast steel tyres without the springs.

The estimated annual value of the steel manufactures of the district is about £100,000, giving employment, at the present time, to about 300 persons, and consuming annually about 15,000 tons of coals. There are in the district nine converting furnaces and 52 cast-steel melting furnaces. The following is a list of the firms possessing those furnaces:—Messrs. John Spencer and Sons, Newburn, 6 converting and 36 melting furnaces; Messrs. Cookson and Co., Derwentcote, 1 converting and 6 melting furnaces; Messrs. Fawcus and Co., Swalwell, 2 converting and 6 melting furnaces; Messrs. Fulthorpe and Co., Dunston, 6 melting furnaces.

As far as can be ascertained, it would appear that the number of persons employed in this trade in 1838 would be from 70 to 80, and the weight of steel produced annually at that time would be about one-ninth the quantity now produced. The prices of steel range from about £18 to £112 per ton, according to the description, the quality, and the size.

This district is highly favourable for the development of the manufacture of steel of the best quality, owing to the facility and cheapness with which a supply of iron can be obtained from Sweden—freights frequently being as low as 3s. 6d. per ton—and also owing to an abundant supply of cheap fuel and labour in the neighbourhood. The business requires, however, the most vigilant attention of thoroughly practical and experienced persons in its management to attain any considerable amount of success.

ON

THE LOCAL MANUFACTURE

OF

LEAD, COPPER, ZINC, ANTIMONY, &c.

BY

T. SOPWITH, M.A., F.R.S., AND T. RICHARDSON, M.A., F.R.S.E., &c.

LEAD MINING DISTRICTS.

The mining districts are chiefly situated in, or near, the centre of that narrow portion of Great Britain, which is formed by the counties of Northumberland, Durham, Cumberland, and Westmorland, and may be considered as being nearly in the central portion of the whole island, being situated midway in its length from north to south, as well as from east to west, between the German Ocean and the Irish Channel.

Under the level lands which lie near to the eastern and western coasts, the upper portion of the carboniferous series of rocks contains numerous and valuable beds of coal. From beneath the coal strata, the "lead measures," as they are locally termed, that is to say the several beds of limestone and other rocks in which veins of lead ore are chiefly found, gradually rise in a westerly direction, with an inclination exceeding that of the general rise of the surface, until they bassett or crop out at the surface of a wide range of country, reaching their highest elevation at the mountain of Cross Fell, in Cumberland, and other adjacent fells or mountain moorlands, which extend in a north and south direction so as form a western limit to the lead mining districts.

The strata which extend between the outcrop of the lowest of the coal strata and the Cross Fell ridge of mountains, are well known in the district as the carboniferous, or mountain-limestone formation, so called from the abundance of coal nearly associated with them, and from the numerous beds of limestone which prevail. These lead mining strata lie nearly midway in the series of formations which are found in England,

SECTION OF THE STRATA
FROM THE FELL TOP LIMESTONE
TO THE LOWEST STRATA IN THE LEAD MINES AT ALLENHEADS
BY T. SOPWITH M.A. F.R.S.

SCALE $\frac{1}{4800}$ of NATURE (400 feet to 1 inch)

		Faths.	Feet.	Inches.
Plate				
FELL-TOP LIMESTONE		0	4	3
Fell-top Hazel		2	1	6
Plate		5	0	0
Whetstone sill		1	2	0
Plate		2	1	6
Hazel		1	5	0
Plate		1	1	6
High Slate sill		4	0	0
Plate		1	1	0
Low Slate sill		3	5	0
Plate		4	4	0
White Hazel		1	3	6
Plate		3	5	6
Ironstone		0	3	6
	Coal	0	1	6
Firestone		4	5	0
Plate		3	4	0
White tuft or White sill		2	2	3
Plate		2	1	0
Girdle-beds		0	3	6
Plate		2	0	3
Pattinson sill		2	0	0
Plate		3	1	6
LITTLE LIMESTONE		1	3	9
Plate		3	1	9
	Coal	0	2	0
High Coal sill		1	2	0
Plate		1	3	0
	Coal	0	2	0
Low Coal sill		1	4	0
Plate		3	1	9
GREAT LIMESTONE	*High Flatt* / *Middle Flatt* / *Low Flatt*	8	5	3
Tuft		1	2	6
Plate		3	2	6
LIMESTONE-POST		0	3	6
Quarry Hazel		4	4	6
Plate		5	2	6
Till-bed		2	0	9
FOUR FATHOM LIMESTONE		3	0	8
Nattrass Gill Hazel		3	1	0
Plate		5	3	6
THREE YARDS LIMESTONE		1	3	3
Plate		1	2	9
Six Fathom Hazel		5	2	0
Plate		0	4	0
FIVE YARDS LIMESTONE		2	3	6

A. Reid Lith. Newcastle.

being as much below the Tertiary beds of the south east part of the island, as they are above the Silurian rocks on the borders of Wales.

A lofty range of elevated land extends from the borders of Scotland to Derbyshire, occupying from 20 to 30 miles in breadth, of the middle portion of the North of England. In many parts of this range of hills extensive lead mines are found, which may be classed under the following districts:—

1st. Mining districts connected with the River TYNE and its tributaries, the NENT, East and West ALLEN, and the DERWENT, namely:—

ALSTON MOOR, in the County of Cumberland.

East and West Allendale, in the county of Northumberland.

Blanchland and Derwent Valley, in the same county.

In addition to these, which form, as it were, distinct mining territories of considerable extent, other valuable mines in detatched places have been discovered, and are extensively worked in the valley of the Tyne.

2nd. The extensive mining district of WEARDALE, in the upper part of the valley of the River Wear, and its tributary valleys of Burnhope, Kilhope, Welhope, Ireshope, Rookhope, &c.

3rd. Another extensive district in Teesdale, in the upper part of the valley of the River Tees, the mines being situated chiefly in the county of Durham, and partly in Yorkshire, and for the most part worked by the London Lead Co.

The geographical position of these districts may be readily understood by referring to ordinary maps of this part of England, and by assigning to the upper part of the Rivers Tyne, Allen, Wear, and Tees, an area extending about 20 miles from their respective sources, and in the Derwent a range of about 10 miles from its source. This would roughly indicate the position of the principal mines.

GEOLOGY OF THE DISTRICTS.

In any view of the history of mining it is impossible to overlook its connection with geological conditions, on which the very existence of the mines depends. The mind is thus carried back to a remoteness of time for which an adequate expression has not yet been defined. The deposition of regularly stratified rocks over a large area of country, exhibits proofs of gradual progress extending over enormous periods of time.

Midway in this vast period, we find, in certain parts of the North of England, evidences of volcanic action, which has interposed basalt among the strata of sandstone, shale, and limestone. The results of this protrusion, not only affect the subterranean operations in mines, but they also appear prominently at the surface, and give rise to some remarkable features of the scenery.

The "Whin Sill," as it is locally termed, interrupts the gradual flow of the River Tees by a barrier, over which that river falls at High Force, near Middleton-in-Teesdale, and it is the cause of the romantic cataract called the Cauldron Snout, near the source of that river; precipitous cliffs of basalt, near Holwick, were formerly connected by a chain bridge, one of the first—if not the earliest—of that construction in Europe. The same overflowing of basalt, which occasions these and other striking features of landscape scenery in Teesdale, extends in a north-eastern direction, and occasionally forces itself on the attention by the manner in which it seems to have invited the erection of works of art; this rock by its greater hardness, having withstood the abrading action which wore away the softer rocks, presents a firm foundation for buildings designed to be as strong as possible. Thus, for a considerable distance along the line of the Roman Wall, we find that the direct course from Chesters to near Haltwhistle was forsaken, and the wall built further north on the summit of precipitous crags of basalt. The pleasure grounds of the Duke of Northumberland, at Ratcheugh, near Alnwick, afford an example of the protrusion of this rock. Dunstanborough Castle, Bamburgh Castle, and Holy Island Castle may be mentioned as interesting places on this account. But the underground occurrence of basalt concerns still more nearly the practical operations of the miner, and involves much costly labour.

HISTORICAL NOTICES.

Old writers on mines and mining, were seldom content to rest with a less remote antiquity than Creation itself; and it curiously marks the state of geological science, even so late as 1670, when Sir John Pettus wrote his History, Laws, and Places of the Chief Mines and Mineral Works in "England, Wales, and the English Pale in Ireland." The hills and dales were treated of by him as having been watery billows formed, by the breath of the Almighty, into hills and valleys, which, says the writer, "have ever since continued in these wonderful and pleasant dimensions." The same quaint writer speaks of Adam, not only as a miner, but also as a

refiner, &c., and nothing, he adds, shows wisdom more than the getting of gold by proper courses. The allusions made by some of the early writers to the getting of gold, and the minute directions which they give for the washing of gold found on the surface, warrants a belief that this precious metal was formerly prevalent on the surface, and it is by no means unlikely that its greater abundance in ancient than in modern times, was one of the attractions which led to the peopling of the island by strangers, and that Britain was, in ancient times, to Rome and other nations, what California and Australia are in our day; certain it is, that gold and silver have from early times been specially reserved by the Crown, and some remains of this are still apparent in the state of the law relating to treasures of these metals found under the surface of the earth.

Owing to many circumstances, Alston Moor is best known as a lead mining district. It has been open to public enterprise, and it forms a good type of the general condition of the lead mining districts. Of its early history, little is known. Its occupation by the Romans is attested by the extent and perfect preservation of some of their large works, and the position of the mineral veins in it and the adjacent districts, is such as to render it probable that lead veins were observed and worked. The formation of the military road, called the Maiden Way, must have exposed to view the mineralogical character of the rocks over which it passed, and the lead found in the Roman station at Whitley, was probably obtained from the immediate vicinity. Traces of ancient smelting places exist, as may be inferred from the scoriæ yet to be found, but of any detailed operations or exact localities there are not, that we are aware of, any records. It is not until about six centuries ago, that any light appears by which to judge of the state of the mining districts, and even then, and for some centuries after, few and far between, and vague and undefined, are the indications of lead mining. The insecurity of property at that time, the more especial uncertainties of Border property, for even then the Kingdom of Scotland included Cumberland, although the mining rights were claimed by the English Crown. In the time of Henry IV. a lead mine is mentioned as having been in Essex, and Sir John Pettus enumerates the following counties as producing lead ore containing silver, viz., Devonshire, Gloucestershire, Worcestershire, Staffordshire, Leicestershire, Cheshire, Derbyshire, Lancashire, Cumberland, Northumberland, Yorkshire, Bishopric of Durham, Flintshire, Denbighshire, Shropshire, Caernarvonshire, Merioneth, Montgomery, Carmarthen, Brecknock, Monmouth, Buckinghamshire, and Dorsetshire.

From this it may be seen that for a long period, lead mining operations have been extensively spread over a great part of England and Wales, whilst in Scotland, the chief works were almost entirely confined to Leadhills, a place were gold was formerly obtained in some abundance. More accurate records would probably throw further light on the question, whether in mining districts in the southern parts of the island gold was, or was not, among the early inducements to search for hidden treasures.

In Sir John Pettus' definition of poor mines, and of rich mines, or "Mines Royal," he states that where the ore digged from any mine doth not yield, according to the rules of art, so much gold or silver as that the value thereof doth exceed the cost of refining, and loss of the baser metal wherein it is contained, or from whence it is extracted, then it is called poor ore, or a poor mine.

On the contrary, where the ore digged from any mine doth yield, according to the rules of art, so much gold or silver as that the value thereof exceeds the charges of refining and loss of the baser metal in which it is contained, and from which it is extracted, then it is called rich ore, or a "Mine Royal," and it is appertaining to the King by his prerogative. In this we have the definition of the limits within which it appears the mines of Alston were included as mines royal, and the importance of which, is prominently marked in the several charities which the Kings of England, in several successive reigns, conferred by virtue of that prerogative.

Sir J. Pettus states that the mines in Devonshire, Somersetshire, and Cornwall were wrought by the Romans, who in the period of 300 or 400 years that they occupied the mining districts of the North of England, doubtless exercised their knowledge of the art, and Cæsar expressly mentions that one reason of his invading the Britons was, because they assisted the Gauls with the treasures with which their country did abound. It appears, moreover, that in these times and long after, the practice was to condemn to the mines, those who had committed any heinous offence against the laws of the land.

In the beginning of the fourteenth century (1304), mention is made of indemnities granted to miners in Cornwall, and liberty to turn watercourses for their works at pleasure. Thirty years later, certain mines of lead, mixed with gold and lead ore, are mentioned in Shropshire. "A concealed mine of gold" is referred to (1401) in a letter of Mandamus, and in 1426, Henry VI. granted to John Duke of Bedford "all mines of gold and silver within his Kingdom of England for 10 years, paying the tenth

part to the Holy Church, to the King the fifteenth, and to the lord of the soil the twentieth part." In 1438, the same King granted to John Sellers, all mines of gold and silver in Devon and Cornwall, and all mines of lead holding silver and gold, to hold (from the expiration of twelve years, formerly granted to the Duke of Bedford) for 20 years, paying the fifteenth part of pure gold and pure silver. In 1451, the same King made his chaplain, John Boltwright, comptroller of all of his mines of gold and silver, copper, lead, &c., within the counties Devon and Cornwall, and in the following year, the same Boltwright is mentioned as "provost and governor of all his mines," and a grant was made to him of all mines of copper, tin, and lead in Devon and Cornwall, to hold during his good behaviour, paying the tenth part of pure gold and silver, copper, tin, and lead, with power to let and set for 12 years, paying to the King the tenth bowl of ore, &c., holding gold or silver, and to dig without interruption, &c.

These notices, some of them referring to mines generally, and others only as contained in certain counties, are curious as showing the manner of the Crown's disposal of them. The constant mention of gold and silver is quite different to any mining conditions of modern times, and the limited periods of 10 or 12 or 20 years, would seem to imply that no large works were contemplated; the continued security for a long period, under which alone extensive and deep mines can now be worked, not being required in virgin mines where the readiness of the implements and machinery were adapted only for operations of an inconsiderable depth.

In 1468, Edward IV. granted to Richard Earl of Warwick, John Earl of Northumberland, and others, all mines of gold and silver, &c., on the north side of Trent, within England, and all mines of lead holding gold or silver in the same parts for 40 years, paying to the King the twelfth part of pure gold and silver, and to the lord of the soil the sixteenth part, with liberty to dig, except under houses and castles, without licence.

In 1475, the same King granted to Richard Duke of Gloucester, Henry Earl of Northumberland, and others, the mines of Blanchland called Shildon, in the county of Northumberland, and the mine of Alston Moor, called Fletcher's, the mine of Keswick, in Cumberland, and the copper mine near Richmond, to hold the same for 15 years, paying to the King the eighth part, to the lord of the soil the ninth part, and to the curate of the place a tenth part as they arise.

In 1478, the same King granted (on surrender of the former grants) to William Goderswick and Doderick Waverswick all mines of gold, silver, copper, and lead in Northumberland and Westmoreland, to hold the same

for 10 years, paying to the King a fifteenth part, and to the lord of the soil and to the curate as they can agree.

In 1486, Henry VII. by his letters patent, dated February 27th, made Jasper Duke of Bedford and other Earls, Lords, and Knights *Commissioners and Governors* (a designation retained until very lately in the direction of the Estates of Greenwich Hospital) of all his mines of gold, silver, tin, lead, and copper in England and Wales, to answer the profits to the King, and made Sir William Taylor, comptroller, to hold the same for 20 years, with liberties of court and other privileges, paying to the King the fifteenth part of pure gold and silver, and to the lord of the soil the eleventh part as it grows.

For a period of about 50 years following the appointment of this Commissioner in the reign of Henry VII., very little appears to have been done, and in the third year of the reign of Queen Elizabeth a society was appointed, entitled the society for the mines royal, to whom a grant of gold, silver, and copper was given within the counties of York, Lancaster, Cumberland, Westmoreland, Cornwall, Devon, Gloucester, and Worcester, as also in Wales, with liberty to grant and assign parts and portions. The various laws and regulations of this and similar societies, do not throw any light on the local details of mining. The general rate of duties and conditions of the North of England lead mines, in the above periods, can only be inferred from the probability of their having been included in some of the grants already recited.

In other lead mining districts, we find more minute details of local customs; such, for example, are the laws of the lead mines of Derbyshire, and Mendip in Somersetshire, but we find no trace of any of these peculiar customs having prevailed in Alston or the adjacent districts. One of the Derbyshire customs, or regulations, is curious enough—"If any blood be shed upon the mine, the author shall pay 5s. 4d. the same day, or else, shall double the same every day till it come to 100s.; 5s. 4d. was also the apparently moderate penalty in case of underground trespass. The laws and customs are described as being those of the mine used in the highest peak, and in all other places through England and Wales." The miners sued that the King "would confirm them by charter under his Great Seal, by way of charity and for his profit, forasmuch as the aforesaid miners be at all times in peril of their death, and that they have nothing in certain but that which God of his grace will send them."

The information to be thus gleaned is scanty enough, and does not admit of being woven into a connected narrative; yet it indicates the scale

of payment to the several parties concerned, the shortness of the term for which grants were made, the absolute right of the Crown, and the participation of a portion of the revenues of the Church. The miners of Alderston or Alston had royal protection granted in 1233, again in 1236, and again in 1237. In 1282, the manor of Alderston was granted by Edward I., to hold in fee of the King of Scotland, reserving to himself and to the miners various privileges, especially such as belonged to the franchise of Tindale, within which Alston was then comprised.

The details of grants and charters more immediately relating to Alston, appear to correspond in general terms with those more general grants which we have specified, as elucidating the early progress of mining in this kingdom generally. In 1333, several of the privileges above alluded to were confirmed to Robert, son of Nicholas de Veteripont, and in the following year, some further liberties were confirmed, from which it appears that Alston, at that period, had not only mines but a mint. These and some other details are contained in a brief account of the mining districts, which one of the writers drew up more than 30 years ago, when residing in Alston Moor.

The ancient names of parks and forests, which occur in these northern mining districts, as applied to extensive tracts of land which are now treeless, are worthy of mention, as they indicate in a striking manner the abundance of forest timber which once adorned the now nearly treeless districts under consideration. In 1290, Patric of the Gill and 26 other miners were empleaded by Henry de Whitby and Joan his wife for cutting down their trees at Aldeneston by force and arms, and carrying them away, to the value of £40. The miners claimed that they held the mine of the King and were privileged to cut wood. The context sufficiently indicates that there had existed in former times vast quantities of wood, that it was extensively used for the mines, and that the county was thus rendered bare and treeless, in which state, only too much of it yet remains.

Another intimation contained in these ancient records, leads to the supposition that mining cases were at one time subject to the decision of juries of miners, similar to those which existed in other parts of the kingdom, and the proceedings of such juries, one of the writers had occasion to investigate more closely in connection with the Forest of Dean.

Alston Moor afterwards became the property of the Hyltons, of Hylton Castle, in the county of Durham, and a lease was granted in 1611 for 999 years by Henry Hylton, subject to the payment of certain rents which

amounted to £64. In 1629, the manor was sold to Sir Edward Radcliffe for £2500, and it remained the property of that family till the confiscation of the estates of James Earl of Derwentwater in 1716. It was granted by the Crown in 1734 to the Royal Hospital for Seamen at Greenwich, and has ever since remained in the possession of the Commissioners in trust for that institution. Adjoining estates have subsequently been purchased and added to the original tracts of land so given.

It would be a work of some labour to extend these notices to the details of property and succession in the several other districts. The only practical result would be to discover a period when general and undefined royal rights were gradually brought into narrow compass by increasing population, and when mining was doubtless encouraged by liberal immunities granted to miners. It would be difficult to pursue in any minuteness the gradual advance of improvement, and of distinct rights of property over clearly defined districts. The royalties of Allendale passed into possession of the Fenwicks, of Wallington, of the Blacketts, and eventually of the family of the present possessor, Wentworth Blackett Beaumont, Esq., M.P. The Weardale mines are held under lease by the same owner from the Ecclesiastical Commissioners. The mines in Teesdale belong to various lords, of whom the Duke of Cleveland is the chief, and at, and near Blanchland, in the valley of the Derwent, the royalties belong to H. Silvertop, Esq., and other proprietors. It is interesting to mark how the former vague and uncertain mode of mining in these lead districts was replaced by more exact methods, and we apprehend that such a period of change may be distinctly traced in the supervision of that great engineer Mr. Smeaton, who was for a time the agent of the lead mining properties of Greenwich Hospital in this district. It is certain that one great work which he projected and commenced at Alston, in 1775, gave a new stimulus to mining. This was the Nent Force level, a work of great magnitude, of vigorous conception, well adapted to the then existing state of information, and to the imperfect state of engines where great power was required. In the present day an equal amount of exploration and drainage may be pursued by the use of hydraulic engines wholly worked by water. About the same period, the progress of mining in Allendale owed much to the ingenuity of Mr. William Westgarth, who first introduced water pressure engines. The generous interest taken by Smeaton in the promotion of so useful a discovery, may be seen by his communications to the Society of Arts. The minute details of the construction of Mr. Westgarth's

engine are contained in the early volumes of the Transactions of that society. "The old man" is the local phrase by which ancient mining excavations in these districts are described. The greater or less abundance of produce of lead was scarcely matter of public interest, nor were the fluctuations of price felt by the general public as in the case of coal. Carried on in remote districts, which, until half a century ago, were in many places almost inaccessible except on ponies, it is not surprising that few details of the local history of lead mines, of an authentic and detailed character exist; or that, we have only meagre traces of a secluded district, and of a people shut out in a great measure by their occupation, even from the few dwellers on the surface of their own remote dales.

METHODS OF WORKING LEAD MINES.

The earliest method of working lead mines, appears to have been by shafts, and by following the surface indications of ore downwards. The driving of levels for drainage in Dean Forest, was of later origin, and probably so in the other mining districts of the kingdom. The work was drawn to the surface in kibbles or small tubs, and some of the smaller pits on the bassett of inferior beds of coal, now present, what probably was, the appearance of a respectable mine in the infancy of such operations. The general use of levels or galleries large enough to admit of horses travelling in them, is said to have been introduced into the lead mining districts, by Sir Walter Calverly Blackett, about 120 years ago; but the example was not, as we believe, followed for many years by other mine owners. Cast iron rails instead of wood, were first used in Nent Force level. Tin pipes were first used for ventilation by Low, Carlisle and Co. at Tyne bottom mine. Mr. Stagg introduced iron pipes at Rampgill, and Mr. Dickinson first used lead pipes for the purpose of ventilation in the Nent Force level. Any of these materials were an improvement on the wooden boxes, which rapidly decayed, and so rendered the air impure, and which, moreover could with difficulty be kept water-tight.

In concluding this part of our Report, one prominent feature may be mentioned, viz., the work called the Blackett Level, commenced by W. B. Beaumont, Esq., M.P., in his manorial property in East Allendale. The shafts on this work were commenced in 1855, and the adit level, near Allendale Town, was begun in 1859. The entire length, when completed, will be nearly seven miles.

At three of the shafts, and also at the Allenheads mines, are several extensive adaptations of the improved hydraulic engines invented by

Sir Wm. Armstrong, and particularly described by him at the meeting of Mechanical Engineers held in this town.

STATISTICS.

The quantity of lead ore raised in this northern district, and smelted in the different mills, in 1861, according to Hunt's Mineral Statistics, was as follows :—

	Lead Ore. Tons.	Lead. Tons.	Silver. Ounces.
Durham and Northumberland ...	19,536 ...	15,252 ...	78,265
Cumberland	6,324 ...	4,614 ...	37,115
Westmoreland	2,392 ...	1,576 ...	21,214
Yorkshire	8,801 ...	6,203 ...	3,650
	37,053	27,645	140,244

And the following tables furnish several details of the production of lead in the counties of Cumberland, Northumberland, and Durham.

PRODUCE OF LEAD IN THE YEARS 1845 TO 1862 INCLUSIVE, IN THE COUNTIES OF CUMBERLAND, DURHAM AND NORTHUMBERLAND.

Name of Mine.	1845.		1846.		1847.		1848.		1849.		1850.		1851.		1852.		1853.	
	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
CUMBERLAND.																		
Alston Moor Mines	4615	..	4330	..	4470	..	4390	..	4921	7	5155	11	4794	12	4210	15	3865	19
Roughtingill	87	..	..	..	..	..	..	..	..	..	64	..	..	..	..	..	135	..
Driggith Beck Waste	10	..	2	..	24	..	15	..	..	..	..	..	..	..	..	..	..	..
Dry Gill Mine	..	..	6	..	8	..	27	..	30	..	1	..	..	..	..	..	..	..
Driggith Mine	37	..	18	..	..	..	..	..	..	..	75	8	..	..	..	..	160	..
Greenside	1100	..	1200	..	1200	..	1200	..	1300	..	1420	..	1420	..	1466	..	1150	..
Keswick Mines	..	..	..	..	..	..	14	..	35	..	107	5	73	10	137	..	63	..
Tynehead Mines	..	..	..	..	..	..	96	..	41	..	27	..	34	..	50	..	55	10
Goldscope	..	..	..	..	..	..	..	..	..	..	..	..	11	..	14	..	190	..
Brandlehow	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sundries	12	..	..	..	..	..	12	..	..	..	..	..	..	..	..	..	..	..
Total	5861	..	5556	..	5702	..	5684	..	6327	7	685[illegible]	4	6333	2	5877	15	5619	9
DURHAM AND NORTHUMBERLAND.																		
E. and W. Allendale and Weardale	8502	..	8372	..	9300	..	9080	..	9162	..	9804	..	9977	..	10818	..	9904	..
Teesdale Mines	1683	..	1870	..	1870	..	2490	..	2576	..	3220	11	3769	1	3446	..	2630	..
Derwent Mines	..	..	..	..	1033	..	1046	..	1001	..	1280	..	1200	..	875	..	1000	..
Stanhope Burn	..	..	..	..	..	..	160	..	..	..	280	8	231	1	218	16	..	..
Holly Well	..	..	..	..	..	..	48	..	51	..	582	..	18	..	20	..	7	..
Lane Head	..	..	..	..	..	..	17	..	8	5	18	..	20	..	20	10	16	4
Aller Gill	..	..	..	..	..	..	8	..	..	..	11	..	6	10	1	18	..	..
Bollihope	..	..	..	..	..	..	9	..	5	1	9	..	7	..	22	..	8	..
Fallowfield	..	..	..	..	..	..	45	..	88	..	120	..	122	..	80	..	160	..
Whitfield	..	..	..	..	..	..	105	..	54	..	19	..	15	..	8	10	11	..
Langley Barony	..	..	..	..	..	..	..	..	851	..	2	..	..	..	..	..	..	..
Settlingstones	..	..	..	..	..	..	..	..	260	..	875	..	..	..	735	..	712	..
Brandon Walls	..	..	..	..	..	..	..	..	..	..	79	..	78	..	76	..	66	..
Healyfield	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	250	..
Stone Croft	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	62	..
Flakerigg	..	..	..	..	..	..	..	..	..	..	..	..	..	..	89	18	81	5
Sundries	58	..	42	..	42	..	170	..	10	..	40	4	45	..	71	19	83	16
Total	10248	..	10284	..	12245	..	13178	..	14066	6	15840	8	15488	12	15978	11	15041	5

Name of Mine.	1854.		1855.		1856.		1857.		1858.		1859.		1860.		1861.		1862.	
	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
CUMBERLAND.																		
Alston Moor Mines	4914	6	4887	12	4877	12	3831	16	4052	17	4051	9	3948	5	3645	10	4159	2
Roughtingill	120	..	305	..	345	..	296	..	253	..	221	..	263	..	228	12	211	4
Driggith Beck Waste	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Dry Gill Mine	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Driggith Mine	195	..	190	..	165	..	171	7	156	..	187	14	187	9	108	15	122	17
Greenside	1100	..	1100	..	Returns not received.						..	..	..	..	..	..	1000	..
Keswick Mines	33	10	96	..	..	..	..	..	..	..	..	..	178	..	..	..	80	5
Tynehead Mines	56	10	125	15	128	9	151	18	88	5	119	9	45	10	85	5	41	4
Goldscope	243	..	303	..	305	..	255	..	388	..	300	..	325	..	348	2	348	2
Brandlehow	..	..	92	10	..	..	..	..	280	..	..	..	222	..	225	4	219	12
Sundries	..	..	..	..	..	..	..	..	..	..	421	2	..	..	..	..	66	4
Total	6662	6	6929	17	5821	1	4706	1	5168	2	5250	14	5119	4	4581	8	6241	10
DURHAM AND NORTHUMBERLAND.																		
E. and W. Allendale and Weardale	9200	..	9081	..	9437	..	8974	..	8448	..	7659	..	6925	..	8120	..	8300	..
Teesdale Mines	5018	16	4508	10	4755	..	4535	9	4645	19	3446	11	3863	16	3485	8	3639	4
Derwent Mines	800	..	1240	..	1850	..	1120	..	1106	..	1100	..	1010	..	1051	12	1011	..
Stanhope Burn	144	..	194	2	208	16	99	8	67	10	76	10	..	..	..	..	..	..
Holly Well	4	..	1	5	8	6	5	..	..	..	..	..	..	..	..	..	..	..
Lane Head	2	10	8	..	28	6	22	..	10	10	8	12	10	..	6	6	10	6
Aller Gill	..	..	..	..	6	..	2	10	..	8	..	..	..	..	..	..	..	..
Bollihope	8	..	13	2	18	..	16	17	124	..	213	..	235	10	188	2	80	..
Fallowfield	144	..	150	..	150	..	227	11	300	..	419	8	325	6	336	..	246	13
Whitfield	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Langley Barony	..	..	..	..	..	..	..	..	89	18	68	4	11	4	83	7	65	14
Settlingstones	840	..	600	..	925	..	1350	..	1120	..	750	..	910	..	856	..	865	15
Brandon Walls	45	..	40	..	56	5	60	..	54	..	62	2	58	7	58	2	67	17
Healyfield	280	..	330	..	445	..	60	..	130	..	80	..	116	..	190	..	296	..
Stone Croft	125	..	165	..	290	..	465	1	480	..	1000	..	900	..	690	..	918	15
Flakerigg	82	8	..	..	..	..	..	..	285	..	..	..	753	12	728	12	810	..
Sundries	50	10	44	..	1	18	86	5	5	2	..	..	91	7	52	17	692	16
Total	16684	4	16309	19	17674	11	16978	16	16816	2	14883	1	15908	2	15286	6	16454	..

LEAD ORE, LEAD AND SILVER, THE PRODUCE OF CUMBERLAND FOR 10 YEARS ENDED 1862.

Years.	Lead Ore. Tons.	Cwts.	Lead. Tons.	Cwts.	Silver. Ounces.
1852	8,410	17	5,877	15	52,893
1853	8,348	19	5,619	9	50,000
1854	9,890	18	6,662	16	42,020
1855	9,627	13	6,929	17	62,879
1856	7,311	8	5,321	1	51,931
1857	6,450	0	4,711	8	43,460
1858	7,235	13	5,207	14	43,721
1859	7,180	9	5,250	14	39,406
1860	7,041	10	5,130	7	32,806
1861	6,324	9	4,614	13	37,115
1862	7,173	13	5,241	10	41,911

LEAD ORE, LEAD AND SILVER, THE PRODUCE OF DURHAM AND NORTHUMBERLAND FOR THE 10 YEARS ENDED 1862.

Years.	Lead Ore. Tons.	Cwts.	Lead. Tons.	Cwts.	Silver. Ounces.
1852	21,594	3	15,978	11	191,736*
1853	19,287	16	15,041	4	140,000*
1854	22,329	15	16,669	18	78,577
1855	22,107	18	16,309	19	75,435
1856	24,125	7	17,674	11	79,924
1857	21,580	1	17,073	14	74,091
1858	19,999	2	16,776	7	78,238
1859	19,571	0	14,568	0	74,222
1860	20,200	12	15,186	0	84,254
1861	19,536	15	15,252	17	78,265
1862	21,177	18	16,454	0	82,854

PRODUCE OF LEAD IN THE YEARS 1845 TO 1862 INCLUSIVE IN THE COUNTIES OF CUMBERLAND, DURHAM, AND NORTHUMBERLAND.

Cumberland. Year.	Tons.	Cwts.	Durham and Northumberland. Year.	Tons.	Cwts.
1845	5,861	0	1845	10,248	0
1846	5,556	0	1846	10,284	0
1847	5,702	0	1847	12,245	0
1848	5,684	0	1848	13,178	0
1849	6,327	7	1849	14,066	6
1850	6,850	4	1850	15,840	3
1851	6,388	2	1851	15,488	12
1852	5,877	15	1852	15,978	11
1853	5,619	9	1853	15,041	5
1854	6,662	6	1854	16,684	4
1855	6,929	17	1855	16,309	19
1856	5,321	1	1856	17,674	11
1857	4,706	1	1857	16,973	16
1858	5,168	2	1858	16,816	2
1859	5,250	14	1859	14,883	1
1860	5,119	4	1860	15,208	2
1861	4,581	8	1861	15,286	6
1862	6,241	10	1862	16,454	0

SMELTING PROCESSES.

Various important improvements have been introduced into the treatment of lead ores; among which we may mention the substitution of

* The Westmoreland silver is included in these quantities.

the Spanish Economico-furnace for the slag hearth, by means of which a better produce of lead is obtained from the refuse products of the mills. This Spanish furnace is a miniature blast furnace covered at the top, from which a flue conveys the fumes to the condensing chambers, or chimney.

Another improvement, introduced since 1839, is the celebrated desilverizing process of the late Mr. H. L. Pattinson, by which large quantities of both lead and silver have been saved. This process is now so well known that it is not necessary to describe it on the present occasion, as it was fully explained in a previous report to the British Association.

A third improvement is the conversion of hard into soft lead by the process of calcining, introduced by Dr. Richardson, at Blaydon, in 1840. This process consists in exposing the hard lead in a melted state to a current of hot air, by which the antimony and other impurities are oxidized. The oxides float on the surface of the molten lead and are skimmed off from time to time. This operation is continued until a sample of the lead drawn from the furnace is found to be soft and malleable. The late Mr. George Burnett, junr., applied this process to the softening of Spanish lead, and employed a large metal pan, set inside the furnace, in which this hard lead is melted. This improvement has been the means of developing a most extensive trade between this country and Spain. The Spanish ores on the east coast of Spain are smelted with the fuel exported from this country, and the hard lead is brought here to be softened and refined. The following table shows the gradual development of this trade.

IMPORTS OF LEAD INTO NEWCASTLE-ON-TYNE.

	Tons.		Tons.
1844	213	1854	6,534
1845	1,433	1855	8,723
1846	3,969	1856	8,391
1847	2,276	1857	4,877
1848	1,697	1858	4,871
1849	3,958	1859	9,069
1850	7,287	1860	9,373
1851	11,915	1861	12,284
1852	7,317	1862	12,459
1853	7,421		

This hard lead contains on an average about 50 ounces of silver per ton, so that the quantity of silver extracted on the Tyne is now upwards of 600,000 ounces per annum.* Several improvements have also been

* The total imports of lead into this country, in 1861, were 23,109 tons, of which a considerable proportion was from Linares, in Spain. This lead contains very little silver, and the average contents may be therefore taken at 40 ounces per ton on the total imports.

The total production of British mines in 1861 was, lead 65,643 tons, and silver 563,731 ounces. Hence the imports and production of these metals, in this district, amount to 45 per cent. of the lead, and upwards of 50 per cent. of the silver of the whole trade of Great Britain.

introduced for condensation of the fumes evolved in the various smelting and refining operations to which lead is submitted. The first, in point of time, is the horizontal flue or chimney, which was first used by the late Messrs. Crawhall and Johnstone, in Mr. Beaumont's extensive mills. These flues are built of masonry, 8 feet in height and 6 feet wide. The aggregate length of the flues, in the mills belonging to Mr. Beaumont, is 9 miles.

Another plan, adopted in the mills of the London Lead Company, is the invention of the late Mr. Stagg. It consists in drawing the entire gaseous products of the furnaces through water, by means of powerful pumping machinery. The lead fume is completely condensed, and easily separated from the water, on being allowed to collect and remain at rest in suitable tanks.

Mr. Stokoe's plan has been introduced at Langley and other smelting establishments. In this plan, the lead fumes are driven by a fan blast through a series of ascending and descending columns, partially filled with brushwood on pebble stones, down which a stream of water falls, to condense the lead fumes. The water collects in tanks at the bottom of the columns, and the fume is allowed to subside.

We have heard that a small quantity of pure ore is reduced in crucibles by means of iron, similar to the process employed in treating antimony ore, with the object of obtaining a lead of great purity for the production of red lead, to be used in the manufacture of flint glass.

MANUFACTURING PROCESSES.

This locality has long been celebrated for its manufactured leads. The first establishment is said to have been commenced about a century ago, and those at the Ouseburn and Gallowgate were erected about the year 1799.

WHITE LEAD.

The greater portion of this article is manufactured by the old Dutch process, and we have no important improvement to notice. The levigation is conducted with improved machinery, and the yield of white lead has increased with a greater attention to the conditions necessary to insure a more perfect corrosion of the lead.

Mr. Pattinson's beautiful process for making oxychloride of lead is worked at Washington. This plan consists in decomposing lead ore by hydrochloric acid, when a pure chloride of lead is easily obtained. This substance is then partially decomposed by an earthy base, leaving an

amorphous oxychloride of lead behind, which is used in the same way as ceruse, or white lead.

RED LEAD, &c.

The manufacture of orange and red lead, and litharge, is still conducted in the same way, but in every case with improved and more effective machinery.

SHEET LEAD AND PIPE.

The manufacture of these articles has largely increased, and much more powerful machinery has been introduced, by which the sheet lead is now made of a greater width than formerly. Messrs. Walker, Parker, and Co. manufacture a tinned lead pipe, which admits of its use in many cases where a leaden surface would be objectionable.

SHOT

Has been long manufactured here. The Shot Tower is a striking object, which is seen towards the west of the town, on the banks of the river. It was erected at the close of the last century, to carry out the patent process of Mr. Watts. A short time afterwards, the late Mr. Burnett, with great shrewdness, substituted an old pit shaft at Wylam for the purpose of casting the shot.

The manufacture of shot embraces several interesting processes, but as no recent improvement has been introduced, we must limit our remarks to the above brief historical notices of this branch of manufactured leads.

STATISTICS.

From the information which has been kindly furnished by Messrs. Forster, Leithart, and Parker, we are enabled to give the following details of the quantities of these articles made in this district:—

	Tons.
White lead and paint	7,500
Red lead	4,500
Litharge	800
Sheet lead	4,500
Lead pipes	1,500
Shot	750
	19,550

COPPER.

The smelting of ores of copper in this locality is of recent origin, and

is due to the importation of cupreous pyrites, which is used by the alkali makers for the manufacture of sulphuric acid.

The chief supply is obtained from Spain, but the pyrites which arrives from Cornwall, Ireland, and Sweden, also contains copper. The following analysis, by Messrs. Browell, Clapham, and Marreco, exhibit the composition of these sulphur ores:—

	Cornwall.	Ireland.	Spain.	Sweden.
Sulphur	34·345	47·41	43·52	38·05
Iron	32·200	41·78	40·20	42·80
Copper	0·800	1·93	3·12	1·50
Lead	0·400	—	2·11	—
Zinc	1·325	2·00	0·32	—
Arsenic	0·910	2·11	1·10	—
Silica	29·000	3·93	8·00	12·16
Insoluble matter	—	1·43	—	—
Moisture	—	—	1·54	—
Oxygen and loss	—	—	—	5·49
	98·980	100·59	99·91	100·00

These ores are usually burnt in the ordinary kilns for making sulphuric acid, but one manufacturer on the Tyne employs Longmaid's process for making sulphate of soda, in which case the copper is obtained as sulphate.

The burnt ores are afterwards run down to regulus, either alone or mixed with copper ores and slags, which are imported from the Continent. Some of the manufacturers only carry their operations up to the point of making a regulus with 50 per cent. of copper, while others produce tile copper.

The *lit de fusion* varies with the character of the ore, and the following mixtures are used for the purpose:—

	Cwts.	Cwts.	Cwts.
Raw ore	1	0	0
Burnt ore	20	21	7
Silicious	0	0	18
Copper slags	8	4	0
Sand	3	8	0
Tank waste	0	2	4
Fluor spar	0	0	1½
Coal	0	2	0

Messrs. Mease and Co. dissolve out the copper with sulphuric acid, and precipitate this metal by means of iron.

The quantity of copper ore raised in the northern counties is very small, being only 131 tons per annum, and the imports are given in the following table:—

IMPORTS OF COPPER ORE AND SLAGS.

	1857.	1858.	1859.	1860.	1861.
France	739	80	0	233	74
Norway	556	94	8	9	14
Denmark	1	0	0	0	2
South America	0	111	15	0	0
Belgium	0	0	2	0	0
Germany	0	0	7	0	1
Turkey	0	0	1	0	0

The present annual production of copper on the Tyne is about 700 tons.

ZINC.

The ores of this metal are not very abundant in this district, but blende and calamine are found in the neighbourhood of Alston, and in West Allendale.

Ores of zinc are imported from the Isle of Man and Ireland, through the ports on the west coast, and from the Rhine and Sweden to the Tyne.

A well arranged smelting works has been erected by Mr. Attwood, who employs a modification of the Belgian process for the reduction of the ores.

The annual produce of spelter varies from 750 to 800 tons.

Mr. Hunt gives the following returns of the production of these ores —

	Tons.
Alston—Blende	366
Calamine	135
Sundry mines	95
	596

ANTIMONY.

The ores of this metal are all imported and smelted by one firm, who produce annually about 270 tons. The process of reduction is that generally employed, and we have heard that the sulphur matt is treated with sulphuric acid to obtain green copperas.

ON

THE MANUFACTURE OF ALUMINIUM.

BY

ISAAC LOWTHIAN BELL.

THE progress of the manufacture of this—so far as the arts are concerned—new metal has scarcely been such as to require much to be added to those admirable researches bestowed upon the process by the distinguished chemist, M. St. Claire Deville, of Paris. Upon the introduction of its manufacture at Washington, three-and-a-half years ago, the source of the alumina was the ordinary ammonia alum of commerce—a nearly pure sulphate of alumina and ammonia. Exposure to heat drove off the water, sulphuric acid, and ammonia, leaving the alumina behind. This was converted into the double chloride of aluminium and sodium by the process described by the French chemist, and practised in France, and the double chloride was subsequently decomposed by fusion with sodium. Faint, however, as the traces might be of impurity in the alum itself, they to a great extent, if not entirely (being of a fixed character when exposed to heat) were to be found in the alumina. From the alumina, by the action of chlorine on a heated mixture consisting of this earth, common salt, and charcoal, these impurities, or a large proportion thereof, found their way into the sublimed double chloride, and, once there, it is unnecessary to say that, under the influence of the sodium in the process of reduction, any silica, iron, or phosphorus found their way into the aluminium sought to be obtained. Now, it happens that the presence of foreign matters, in a degree so small as almost to be infinitesimal, interferes so largely with the colour, as well as with the malleability of the aluminium, that the use of any substance containing them is of a fatal character. Nor is this all, for the nature of that compound which hitherto has constituted the most important application of this metal—aluminium-bronze—is so completely changed by using

aluminium containing the impurities referred to that it ceases to possess any of those properties which render it valuable. As an example of the amount of interference exercised by very minute quantities of impurity, it is perhaps worthy of notice that very few varieties of copper have been found susceptible of being employed for the manufacture of aluminium-bronze; and hitherto we have not at Washington, nor have they in France, been able to establish in what the difference consists between copper fit for the production of aluminium-bronze, and that which is utterly unsuitable for the purpose. These considerations have led us, both here and in France, to adopt the use of another raw material for the production of aluminium, which either does not contain the impurities referred to as so prejudicial, or contains them in such a form as to admit of their easy separation. This material is Bauxite, so called from the name of the locality where it is found in France. It contains—

Silica	2·8
Oxide of Titanium	3·1
Sesquioxide of iron	25·5
Alumina	57·4
Carbonate of lime	0·4
Water	10·8
	100·0

The Bauxite is ground and mixed with the ordinary soda-ash of commerce, and then heated in a furnace. The soda combines with the alumina, and the aluminate of soda so formed is separated from the insoluble portions, viz., peroxide of iron, silico-aluminate of soda, &c., by lixiviation. Muriatic acid or carbonic acid is then added to the solution, which throws down pure alumina. The remainder of the process is precisely that which is described by Mons. St. Claire Deville. The alumina is mixed with common salt and charcoal, made into balls the size of an orange, and dried. These balls are placed in vertical earthen retorts, kept at a red heat, and through the heated contents chlorine gas is passed. The elements of the earth, under the joint influence of carbon and chlorine at that temperature, are separated, the carbon taking the oxygen, and the chlorine the aluminium. The latter substance, accompanied by chloride of sodium (common salt), sublimes over, and is collected as a double chloride of aluminium and sodium. In small iron retorts, kept at as high a temperature as iron can bear, a mixture of soda (carbonate of soda) and carbonaceous matter with a little ground chalk is placed. The metallic base of the alkali distils over, and is collected in coal oil.

A portion of the double chloride and sodium, along with fluxes, is exposed to a full red heat in a reverberatory furnace. The sodium seizes the chlorine combined with the aluminium, and thus liberates the latter metal, which falls to the bottom of the fused mass.

Aluminium is used in sufficient quantity to keep the only work in England—viz., that at Washington—pretty actively employed. As a substance for works of art, when whitened by means of hydrofluoric and phosphoric acid, it appears well adapted, as it runs into the most complicated patterns, and has the advantage of preserving its colour, from the absence of all tendency to unite with sulphur, or to become affected by sulphuretted hydrogen, as happens with silver.

A large amount of the increased activity in the manufacture referred to, is due to the exceeding beauty of the compound with copper, already spoken of, which is so like gold as scarcely to be distinguishable from that metal, while it possesses the additional valuable property of being nearly as hard as iron.

This alloy, or aluminium-bronze, as it is termed, is a discovery of Dr. John Percy, F.R.S., and appears to be a true chemical compound. Copper is melted in a plumbago crucible, and, after being removed from the furnace, the solid aluminium is added. The union of the two metals is attended with such an increase of temperature that the whole becomes white hot, and unless the crucible containing the mixture is of refractory material, a vessel which has resisted a heat sufficient to effect the fusion of copper, melts when the aluminium is added.

Messrs. Newall & Co. ascertained, in 1858, that the tensile strength of aluminium wire is only one-third that of iron, and that aluminium-bronze, composed of 10 per cent. of aluminium and 90 per cent. of copper, broke with a strain of 56 tons per square inch. Colonel Strange, of the Royal Astronomical Society, investigated its properties, which were given in a very able paper in the Transactions of that body. Its malleability, ductility, and capability of being finely divided and engraved upon, along with its great strength, induced the Colonel to recommend its adoption in the theodolite used in the Trigonometrical Survey of India.

At the Elswick Ordnance Works, Captain Noble, R.A., confirmed previous experiments on the capability of aluminium-bronze to resist longitudinal and transverse fracture, and in addition to this he ascertained that its position to withstand compression stood halfway between that of the finest steel and the best iron.

The bronze, containing ten parts of aluminium and ninety of copper,

affords an alloy endowed with the greatest strength, malleability, and ductility. The colour of the copper is affected by a very trifling addition of the other constituent, and the alloy gradually improves in these valuable qualities just mentioned, until the proportions given above are reached. After this, *i.e.*, when more than ten per cent. of aluminium enters into the composition of the bronze, the alloy gradually becomes weaker and less malleable, and at length is so brittle that it is easily pounded in a mortar.

Washington Chemical Works, 26*th August*, 1863.

APPENDICES.

No. I.—ON STEEL MANUFACTURE.

Mr. W. Bridges Adams' Wheels with Spring Tyres.

Staffordshire iron tyres, applied to wheels on this principle, have run on the North London Railway, under passenger carriages, a distance of 106,000 miles, without material wear, and without requiring to be turned up; and the following table is from actual comparative results, obtained by Mr. Cross, on the St. Helen's Railway, Lancashire:—

Comparative Wear of Four Classes of Engine Tyres, St. Helen's Railway.

No. of Engine.	Wheels.	Coupled.	Diameter.	Weight.	Miles Run.	Slip.	Remarks.	Class of Tyres.	Quality of Line.	Length of Line.
			Ft. In.	T. C.						Miles.
23	6	4	4 6	19 15	40,848	Even in dry weather.	Needing turning up.	Krupp's steel.	Heaviest gradient, 1 in 85.*	Single .. 10¾
4	6	4	4 6	20 0	20,798	Do.	Do.	Best Yorkshire iron.	Two more do. 1 in 85, 1 in 70.	Double .. 12¼
27	6	4	4 6	23 14	34,006	Do.	Do, and once turned up.	Swedish iron.	Sharpest curve, radius 300 ft.	Other lines 7
18	6	6	4 0	21 0	55,198	Scarcely ever slip.	Not needing turning up.	Staffordshire iron on springs.	Common do., 500 ft. Line many points and crossings.—Twelve miles of sidings in two miles from St. Helen's station.	Total 30

* There is little traffic on this branch, and Nos. 23, 4, and 27 have never worked on it, but No. 18 has worked pretty regularly over it.

Best Yorkshire iron has run half the distance of Krupp's steel, and comparing No. 18 Staffordshire iron (with springs between tyre and wheel), with Krupp's steel, it appears that the former has two more wheels coupled, one-ninth less diameter and one-thirteenth more weight, has run one-third more mileage, scarcely ever slips, the tyres not turned up, nor needing it, and has worked the worst line. The result is that Krupp has now cut rolls for the application of springs to his tyres. Bessemer steel tyres on springs are now applied to another engine, and the whole of the engine tyres are being replaced by spring tyres as fast as they fall in.

In a communication by Mr. Cross, with which the writer of this paper has been favoured, that gentleman calls attention to the fact, that No. 18 engine scarcely ever slips, which at once explains one of the causes for her tyres wearing so well, the other engines having to use rough sand constantly to give them *bite*, causing a

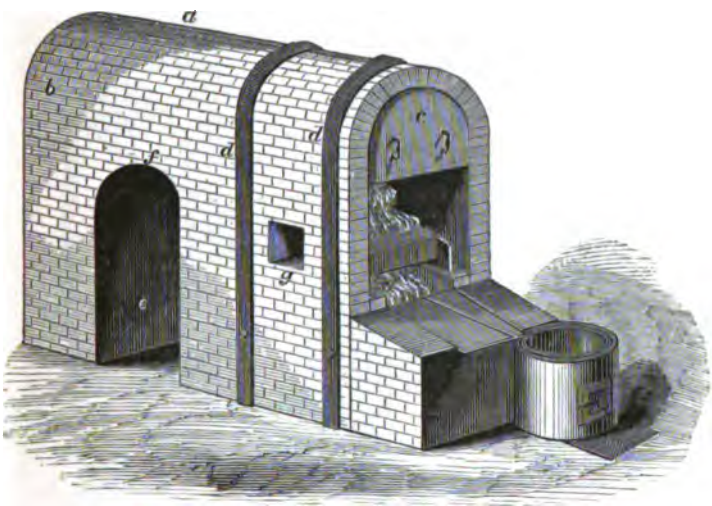
regular grinding action, which No. 18 altogether escapes. This, however, in the opinion of Mr. Cross, in no way detracts from the merit of the spring tyres, his explanation being that the spring allows the tyre to flatten down to a small extent when treading on the rails, presenting a broader surface, and without any external aid, thus giving the required adhesion. Mr. Cross states, that this view is confirmed by his having lately fitted two sister engines, one with and the other without spring tyres, the result being that the engine without these springs cannot at any time take so great a load as the other can ; and he is of opinion that a common iron tyre with springs is, to say the least, equal to the very best Krupp without the springs.

Where Consumed.

The consumers of the steel manufactures of this district are not confined to the locality, for, in addition to these manufactures being sent to almost every part of Great Britain and Ireland, a large proportion is sent to the following foreign countries, viz. :—Austria, Denmark, France, Germany, Holland, Norway, Italy, Russia, Spain, and Switzerland, as well as to Egypt, East and West Indies, North and South America, and Australia.

No. II.—IMPROVED ORE HEARTH.

This furnace is usually constructed with the upper portion open, so that when there is any defect in the draught, the fumes escape into the building in which it is built, and seriously injure the health of the workpeople. Under all circumstances a large opening into the flue is necessary to carry off the fumes, and when the draught is good, a considerable quantity of air passes at the same time, and so far retards the condensation of the lead fume.



In some measure to remedy these defects, Dr. Richardson introduced the following modifications into the ore hearth at Howdon, which have been adopted at some other mills.

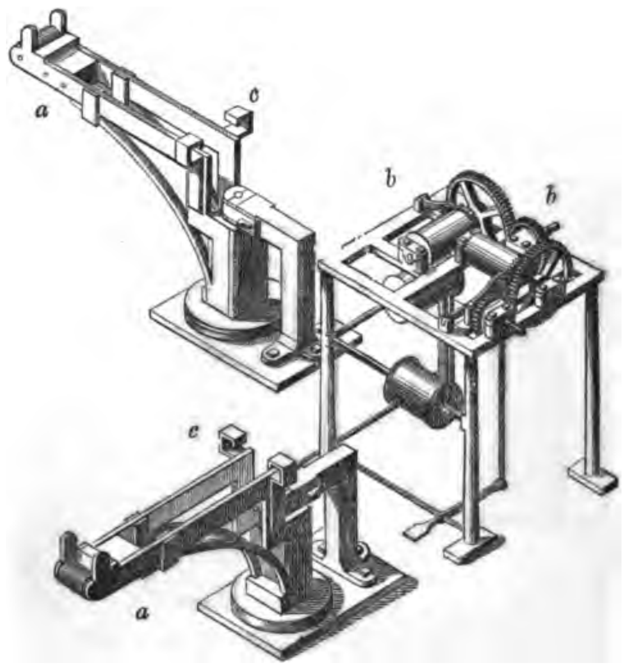
The hearth is covered with a hood of b ickwork *a*, at the back of which there

is an opening into the flue. This opening can be diminished or enlarged by means of a damper, worked from the outside at *b*. The opening in the front can also be regulated by means of a moveable iron plate *c*, which can be raised or lowered according to circumstances. The hood is firmly bound by iron straps *dd*, which are maintained in position by screw bolts, above and below the hearth. The opening *e*, under the arch *f*, allows the workman to regulate the blast, which is admitted at the back through the ordinary tuyere.

The ore is charged through the opening *g*, in the side of the hood, and the furnace is worked from the front in the usual manner.

No. III.—STAGG'S IMPROVEMENT FOR WORKING THE CRYSTALLIZING PROCESS.

Except this improved plan for working the process of the late Mr. H. L. Pattinson, little or no change has been made in the operations. We regret having omitted to give an account of this improvement of the late Mr. J. W. Stagg in our Report read at the Chemical Section, which arose from the haste with which that Report was prepared.



The woodcut will give a much better idea of this invention than any description could furnish.

It consists of a crane and windlass, *ab*; a chain attached to the end of the

shank of the ladle is wound up by the windlass, and draws up the ladle, filled with crystals, out of the pot. A workman guides the handle of the ladle, which is afterwards placed under a catch, *c*, of the crane. The crystals are allowed to drain, which is assisted by an occasional shake by the workman.

This apparatus enables the workman to use a much larger ladle, without expending so much labour as is necessary at present, and a considerable saving in time and labour is said to result by the employment of Mr. Stagg's ingenious invention.

No. IV.—THE SOFTENING OF HARD LEAD.

In reducing the dross which comes from the hard lead, which contains so much antimony, the addition of a small quantity of soda ash, to render the slag more fusible, and thus enable the workman to employ a lower heat, has been found very beneficial. The following analysis of the hard lead obtained from such dross, with and without this flux, proves the advantages of this addition :—

	With 2½ per cent. of soda ash.	Without soda ash.
Lead	58·70	82·88
Antimony	40·66	16·09
Copper	0·32	0·68
Iron	0·32	0·35
	100·00	100·00

When the hard lead, obtained from the dross, is calcined, the process lasts much longer, and the dross, when reduced, yields an alloy much richer in antimony. This process can, however, only be carried on until the alloy contains about equal quantities of lead and antimony.

The following analyses illustrate the progress of the increasing richness of the alloy in antimony.

English Hard Lead.

	Original lead.	1st calcination.	2nd calcination.
Lead	99·27	86·53	52·84
Antimony	0·57	11·29	47·16
Copper	0·12	traces	traces
Iron	0·04	0·34	traces
	100·00	98·16	100·00

Spanish Hard Lead.

	Original lead.	1st calcination.	2nd calcination.
Lead	95·81	64·98	56·60
Antimony	3·66	29·84	43·40
Copper	0·32	5·90	traces
Iron	0·21	0·20	traces
	100·00	100·92	100·00

This alloy is found of great use in casting type furniture, and some of the coarser kinds of type.

An excellent arrangement for treating these hard leads is shown in the accompanying woodcuts :—

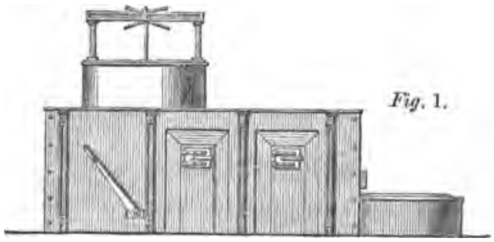


Fig. 1.

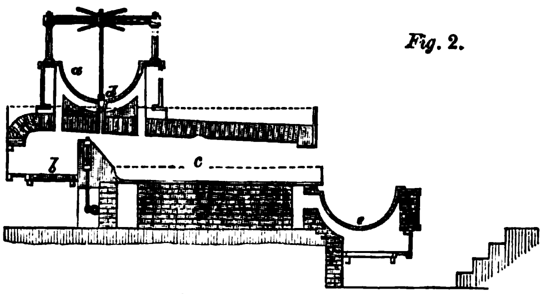


Fig. 2.

Fig. 1 represents a front view, and fig. 2 a longitudinal section, of this calcining furnace.

The hard lead is melted in the pot *a*, which is heated by the fire on the grates *b*. The calcining pan *c*, is supplied with molten lead from the pot *a*, by raising the plug *d*, and thus can always be kept full of lead, until the process of softening is complete. This is an important advantage in calcining the hard dross lead, which sometimes lasts from 10 to 14 days. The soft lead is run into the pot *e*, whence it is ladled into moulds.

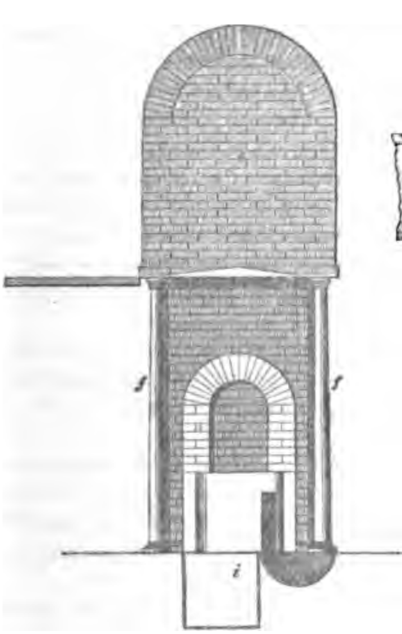
No. V.—ECONOMICO FURNACE.

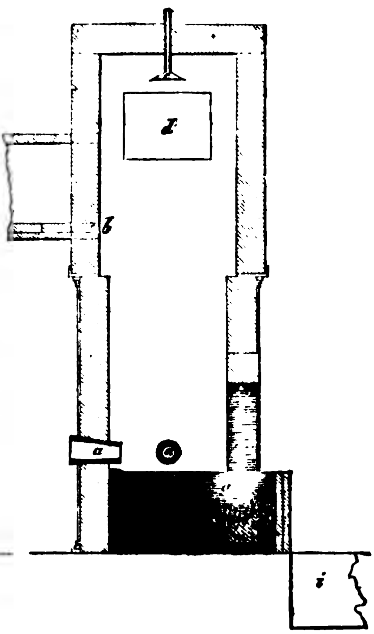
This kind of furnace has been substituted for the English slag hearth, with a great saving of lead. The following woodcuts represent this furnace as improved by Dr. Richardson.

Figs. 1, 2, and 3 represent this furnace, in elevation, section and plan. The blast enters through three water tuyeres *aaa*, and the materials are filled up to the level of the charging door *b* ; the upper layers are kept cool by a fine rain of water from a rose *c*, and the steam which is formed, assists in condensing the fumes, which escape into the flues through an opening *d*, in the side of the top of the furnace. The upper part, *e*, of the furnace rests upon four metal pillars *ffff*, so that when the body of the furnace requires to be renewed, this part remains untouched.

The lead accumulates in the hearth *g*, whence it is tapped, from time to time, into the pot *h*, to be ladled into the pig moulds.

The slag runs continuously into a tank *i*, which is kept supplied with a stream of water.





In the hearth of these furnaces, a spongy kind of metal is occasionally found, which is called a *cuesco* in Spain, and one of which, when analysed, was found to contain as follows :—

Lead	61·35
Antimony	29·50
Copper	8·30
Iron	0·61
Nickel	traces
	99·76

No. VI.—STAGG'S CONDENSING APPARATUS.

The following explanation of the woodcut, is taken from Mr. Stagg's account of his apparatus :—

I attach to the flue or chimney *a*, into which are conducted the fumes, gases, &c., produced at the mill or manufactory, a strong air-tight cistern or vessel of suitable dimensions, and of convenient length to allow as many partitions as may be found necessary or useful, to be arranged two or three feet apart inside. This cistern or vessel may be constructed of wood or other suitable materials, and sufficiently strong to resist the external pressure of the atmosphere when there is an exhaustion or rarefaction of the air inside. To within two or three feet of the bottom of this cistern or vessel, reaches a pipe *b* 1, of corresponding size to the flue or chimney, and descending into the water contained in the cistern, and to which flue or chimney, the pipe is closely and securely connected. The air-tight cistern or vessel is filled with water (admitted by pipes with cocks or other ordinary means) to a sufficient depth to properly condense and purify the fumes that have to pass into or through the same. To an opening in the lid or top of the cistern or vessel, and at the further end thereof, a pipe is united which is connected with one or more air-pumps, *c*, or exhausting machines to be worked by a water wheel, steam engine, or other power. On the air-pumps or other exhausting machines being set in motion, a portion of the air in the connecting pipe, and on the top of the water in the air-tight cistern or vessel is abstracted, whereupon the remaining air in the cistern or vessel becomes so rarefied that the air or smoke in the chimney or flue connected with the pipe that reaches into the water at the bottom of the cistern or vessel, rushes into and through the water in the said cistern or vessel, and an amply sufficient draught is also created to clear the mill or manufactory of noxious smoke, &c.

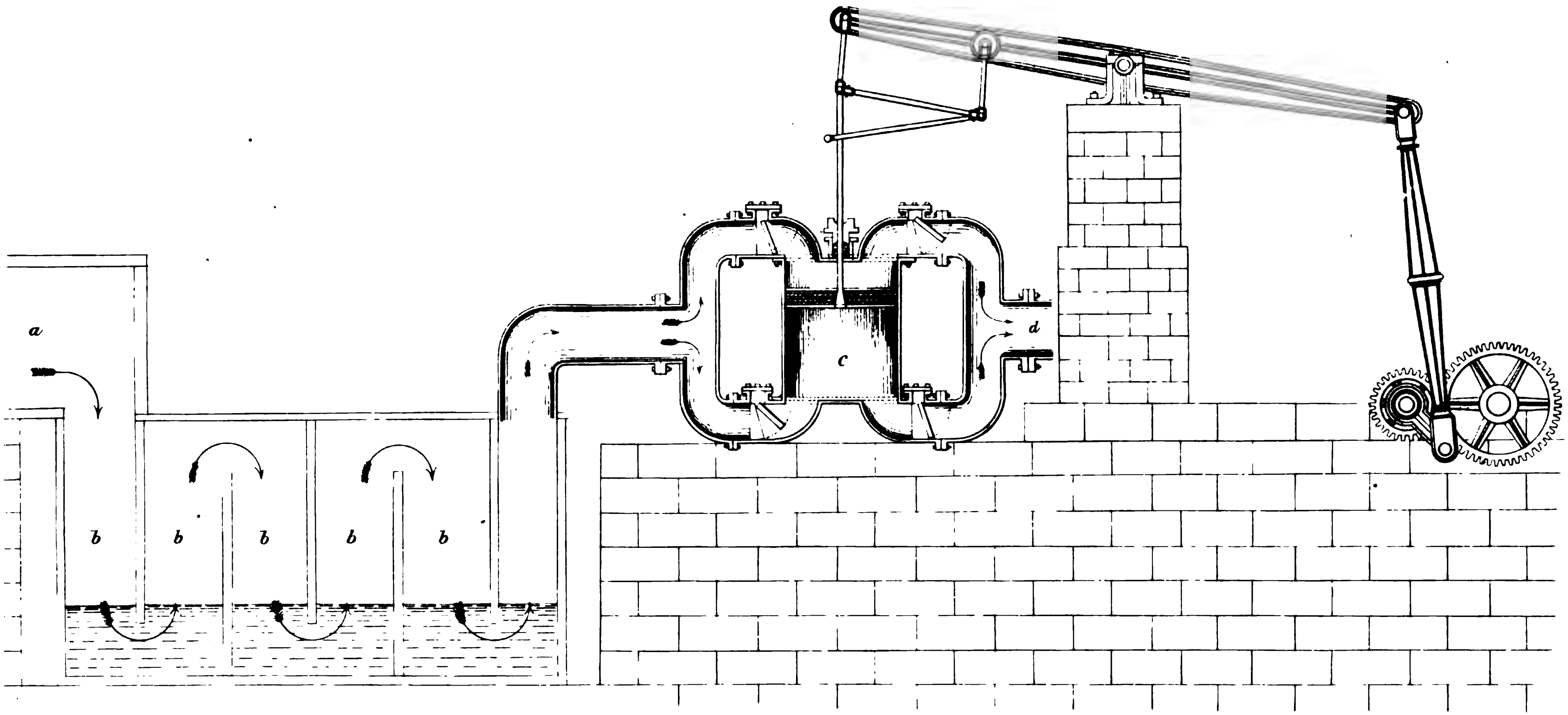
The rushing of air, smoke, fumes, &c., to supply what the air-pumps or other exhausting machines draw off, causes a very considerable motion in the water, and the dashing and spray consequent thereon, very materially aid the washing, condensation, and purifying of the fumes, &c.

This artificial method of creating a draught or current in the chimney or flue leading from the mill or manufactory, is found to overcome the difficulty frequently experienced in attempts to arrest the fumes emitted from the open or blast hearth, which are more liable to return into the mill or manufactory, on meeting with any check, than those discharged from close or reverberatory furnaces.

To enable the fumes, &c., to be drawn through less depth of water in the cistern or vessel, or with a view to their more perfect condensation, and purification, and obtaining the fumes of different degrees of quality, it is advisable to have in the cistern or vessel a number of partitions at suitable distances (see *b*, *b*, *b*, *b*,) for the descent and ascent of the fumes, &c.

Two of these partitions form one compartment, up one space of which the fumes, &c., ascend through the water, and descend down the other. As many of these compartments may be made, or, being made, have water in, as may be found requisite, and likewise the depth of water must be regulated so that nothing but purified vapours and gases, that are not soluble in water, may pass into the air-pumps or other exhausting machines.

STAGG'S CONDENSING APPARATUS.



When this is the case, it will be found that the water in the cistern or vessel becomes highly charged, with metallic and other particles, and products which otherwise would have escaped into the atmosphere and have been lost. The purified vapours and such gases, &c., as are not soluble in water, passing from the cistern or vessel into the air-pumps or other exhausting machines, are forced therefrom into an eduction pipe *d*. The water in the air-tight cistern or vessel when sufficiently saturated, can be run off by cocks or manholes inserted into the sides or ends of the cistern or vessel, and conducted by troughs, into reservoirs, and there allowed to remain in a tranquil state to enable the insoluble fumes or particles to subside.

ON

THE CHEMICAL MANUFACTURES
OF THE DISTRICT.

BY

THOMAS RICHARDSON, PH. D.
JAMES C. STEVENSON.
R. CALVERT CLAPHAM.

CHEMICAL MANUFACTURES.

The following Report on the Chemical Products of this District, has been drawn up from the information which we obtained from the manufacturers themselves, who, with two or three exceptions, communicated to us every detail connected with their works, in the most handsome and liberal manner; and we are glad of this opportunity to acknowledge our obligation to them.

We have arranged the details, as far as possible, in groups according to the actual practice. In other instances, the arrangement usually pursued by chemists, has been adopted, the alkalies, alkaline earths, &c., being taken in order.

We commence with Salt, as the material round which so many products are grouped.

SALT.

Salt works were formerly very numerous in this district, establishments having been formed at Howdon Pans, Hartley Pans, Jarrow, North and South Shields, and other localities. This trade was carried on by several of the most wealthy families in this neighbourhood in the beginning of the last century, and about 200 pans were employed in producing salt, which was extracted from sea-water and brine-springs. Shields salt was the most celebrated salt in the kingdom; and was produced in such quantities at South Shields, as to give a character, and even a nomenclature to this town, which, to this day, is divided into East Pan and West Pan wards. The remains of large hills are still to be seen, formed from the ash of the salt pans. After a time, these ashes took fire, and Mr. R. W. Swinburne, to whom we are indebted for this information, states that the Chapter at Durham are in possession of a picture, representing the burning hills at South Shields.

The production of salt from sea-water in this locality, has given place to that obtained from the brine-springs and rock-salt of Cheshire, and is an illustration of the great changes which take place in the *locale* of manufactures.

A considerable quantity of white salt is still made on the Tyne, from sea water, in which rock salt from Cheshire and Ireland is dissolved, in order to diminish the cost of evaporation.

Two improvements have been successfully introduced in making white salt, which have the saving of fuel as their object. Mr. Wilkinson employs the waste heat of coke ovens for this purpose; and Mr. Fryar dries whiting with the heat which escapes from his salt pans.

ALKALI FOR THIS AND THE LAST CENTURY.*

Two gentlemen, Mr. W. Losh and Mr. Thomas Doubleday, were engaged, unknown to each other, with a series of experiments on the best plan of converting common salt into carbonate of soda. Each of these chemists appear to have used very similar processes; and when the late Lord Dundonald came to reside in the neighbourhood, he was soon on intimate terms with both parties. Both Mr. Losh and Mr. Doubleday tried numerous plans at his lordship's suggestion; but, after spending upwards of £1000, Mr. Doubleday would seem to have tired of making an outlay which promised little or no result.

The first plan tried, was to effect the decomposition of common salt, by means of oxide of lead, and to carbonate the caustic soda, while the insoluble chloride of lead was heated to form a yellow pigment, long known as Turner's yellow.

Another process consisted in decomposing common salt by sulphate of iron. The resulting sulphate of soda was fluxed with coal, and the sulphide of sodium which was formed was carbonated with sawdust. This plan was also worked, some time afterwards, at an alkali manufactory situated near Blyth.

Another process tried was founded on the mutual decomposition of common salt and sulphate of potash. This operation was regularly carried on by Mr. Losh and Mr. Doubleday, whenever the price of the

* The following are the dates at which some of the older alkali works on the Tyne were commenced, as nearly as can be ascertained:—

Mr. W. Losh and others	At Walker	In 1796.
Messrs. Doubleday and Easterby	Bill Quay	1808.
Dr. Hutchinson	Felling	Early in the present century.
Messrs. Cookson	Jarrow	1823.
Mr. J. Allen	Felling	1828.
Mr. C. Attwood	South Shore	About 1830.
Mr. A. Clapham	Friar's Goose	1831.
Mr. H. L. Pattinson	Felling	1833.
Mr. T. Bell	Jarrow	1836.
Mr. R. Imeary	Jarrow	1839.

two potash salts allowed a profit being made; and the chloride of potassium was as regularly sold to the Yorkshire alum makers.

Mr. Losh resided in Paris in 1791, where he acquired a knowledge of chemistry, and soon after his return home, a company was formed to manufacture soda at Walker. The original partners were Lords Dundas and Dundonald, Messrs. Aubone and John Surtees, and John and William Losh. They obtained their salt from a brine spring found in a coal pit at Walker; and the heavy duty upon salt at that date—which was £36 per ton—was avoided by evaporating together a concentrated solution of the brine spring and sulphuric acid; thus obtaining sulphate of soda instead of salt. Another plan adopted by Mr. Losh to avoid the duty, was, to add ground coke, or ashes, to the concentrating salt pan before the salt was formed, and use it in this damaged condition for the manufacture of sulphate of soda.

This was about the year 1796. Messrs. Doubleday and Easterby, in 1808, commenced making sulphate of soda by decomposing the *waste salts* from the soap boilers, which consisted chiefly of common salt and some sulphate of soda. Their chief supply was obtained from the Messrs. Jamieson and other soap boilers at Leith.

They purchased their sulphuric acid at first; but between 1809 and 1810 they got the plans of chambers from Messrs. Tennant, of Glasgow, and erected the first chamber on the Tyne at Bill Quay. They imported the first cargo of sulphur, from Sicily, about the same time, and its arrival in the river excited great attention. At first, the Government returned them the import duty on the sulphur which was used in making acid; and the present Mr. Doubleday remembers having received, at the end of the year, as much as £1500. This, however, only lasted some three or four years, when the duty was repealed. This firm, then trading under the name of Doubleday and Easterby, also erected the first platina retort for making *rectified vitriol*, which cost them £700, and before long, they had three retorts in operation.

The alkali which they made was used in the crude form in the manufacture of soap, in which they were also engaged.

NOTE.—Charles Cooper, an overman at Walker Colliery, informs us that he was employed by Mr. Losh in 1798, and that crystals of soda were then manufactured and sold by Mr. Losh. The salt obtained from the brine-spring on the premises, was evaporated in small lead pans, and was afterwards decomposed by litharge. The soda so produced was crystallized in small lead cones, and when it had stood sufficiently long to crystallize, the cones were turned upside-down to run off the mother liquor. The crystallizing process was then only carried on in the winter months. C. Hunter, Esq., of Walker, further informs us, that in 1816 he sold about half a ton of soda for Mr. Losh to a Mr. Anderson, of Whitby, at £60 per ton.

In 1816, after the conclusion of peace, Mr. Losh returned to Paris, where he learnt the details of the present plan of decomposing sulphate of soda, which he immediately introduced in his works at Walker, and thus may be said to have been the father of the modern alkali trade in this country.

Mr. Doubleday gave the plans of his chamber, furnaces, &c., to the Messrs. Cookson when they commenced their alkali works at South Shields.

This trade has been developed in an extraordinary manner in this locality, where about 47 per cent. of the whole produce of the United Kingdom is now manufactured.

The peculiar advantages of the district are also being recognized, by the fact that the celebrated firm of Messrs. Tennant have purchased land with the intention of removing that part of their works in which the sulphate of soda is converted into alkali, from Glasgow to the banks of the Tyne.

The following details will embrace a brief account of the source of the raw materials, and the various improvements which have been recently introduced:—

SOURCE OF SULPHUR.

Until within the last few years, Sicilian sulphur was almost exclusively employed in this district for the manufacture of sulphuric acid, the pyrites from Wicklow being the only other source of supply. This latter, however, was not sufficiently abundant to render the manufacturer independent of the great fluctuations which have recently taken place in the price of sulphur, on account of the demand consequent on the vine disease.

During the last few years the following additional sources of supply have become available:—1st, Belgian; 2nd, Norwegian; 3rd, Spanish and Portuguese; 4th, Italian; 5th, Westphalian pyrites.

I.—The Belgian pyrites has the advantage of being shipped at Rotterdam at a moderate freight to the Tyne. It is a very hard, compact mineral, containing about 50 per cent. of sulphur, and therefore nearly approaches a pure bi-sulphuret of iron. The burnt residue from one manufactory on the Tyne (the Walker Alkali Works), after being roasted in a lime-kiln to burn off the small remaining portion of sulphur is regularly used as an iron ore at the adjoining iron works. It contains no copper, and from 0·3 to 0·5 per cent. of arsenic.

II.—The Norwegian pyrites is shipped at Levanger; it contains 44 per cent. of sulphur, is easily broken, and does not readily flux in the kiln. The quantity of copper it contains, being less than 1 per cent., the burnt residue cannot be profitably smelted for copper.

III.—The pyrites most generally used, is shipped from Huelva in Spain, and Pomeron in Portugal. The mines are situated on each side of the boundary between the two countries. They were most extensively worked in ancient times, but their recent development has arisen from the use of the ore as a source of sulphur. Containing only 2 to 4 per cent. of copper, it was unable to compete with the richer ores which, from time to time, became available in different parts of the world; but the mining is now rendered profitable by the sulphur having become available, as well as the copper. The per centage of sulphur varies from 46 to 50. The practical difficulty in burning this ore, namely, its great fusibility at the point where the combustion of the sulphur gives rise to considerable heat, has been overcome by the adoption of kilns, first used in Lancashire, in which the area of the surface is large in proportion to the weight of the pyrites consumed.

The use of cupreous pyrites has led to the introduction of the manufacture of copper on the Tyne, which will this year amount to between 700 and 800 tons. The ordinary process of smelting is employed, but the moist method is also being tried; the advantage being, that by this method all the ingredients of the mineral are utilized, the oxide of iron yielding an ore of similar quality to hematite. The smelting process, however, is still preferred in the large manufactories.

In 1860 several cargoes of an ore, containing free sulphur embedded in gypsum, were imported from the island of Milô, in the Archipelágo. From the small quantity of sulphur it contained (19 to 24 per cent.) there was great difficulty in burning it, except the large masses. Subjoined is an analysis of a specimen of one parcel:—

Sulphur	24·00
Gypsum	62·20
Sand, &c.	6·00
Water	7·00

Still more recently, Professor Ansted has discovered a deposit of free sulphur in Corfu, of which he has been kind enough to forward a sample, but we believe it has not been used in commerce.

When sulphuric acid is wanted quite free from arsenic, Sicilian sulphur must be used.

So largely has pyrites displaced sulphur in the production of sulphuric acid, that in 1862 only 2030 tons of sulphur were consumed, against 72,800 tons of pyrites; and, reckoning the above quantity of sulphur as equivalent to 4500 tons pyrites, it appears that 77,300 tons of pyrites are annually used for the manufacture of sulphuric acid, along with 2500 tons of nitrate of soda. Assuming a produce of 120 per cent. on the pyrites, this is equal to a production of 92,760 tons of sulphuric acid, calculated as concentrated. This quantity of sulphuric acid is nearly all consumed where it is made, for the manufacture of other chemicals, such as soda and manures, the quantity sold being only 6440 tons; but this might be most correctly described as consumed in other works, for the quantity sent to a distance is very small. Four-fifths of the sulphuric acid is used for the decomposition of common salt.

SALT AND THE ALKALI TRADE.

The ordinary Cheshire salt is almost exclusively used for the manufacture of alkali; the exception being in one manufactory, where the waste heat of coke ovens is utilized for evaporating the liquor formed by dissolving rock-salt. The former extensive salt-works of Shields are now only represented by one or two comparatively small manufactories of salt, intended entirely for domestic use. Nearly all the salt used in the alkali works is carried by canal to Hull, Goole, or Grimsby, whence it is brought to the Tyne, at a nominal freight, generally by foreign vessels which take it as ballast, when coming to the Tyne for an outward cargo of coals. This is, perhaps, the only practical result of the repeal of that portion of the Navigation Laws that prevented foreign ships from carrying cargoes coastwise.

Within the last few weeks, a discovery has been announced of a bed of rock-salt, at Middlesborough. This discovery may render the alkali trade of this district independent of Cheshire, and develope a large export trade in salt.

The annual decomposition of common salt in the district, is 90,000 tons, requiring 73,800 tons of sulphuric acid, and producing 100,000 tons of dry sulphate of soda. The whole of this quantity is used in the manufacture of alkali. A few hundred tons are consumed in the glass manufacture, which are omitted, as no account has been taken of the sulphate of soda made from the nitrate of soda in the sulphuric acid process.

The alkali is produced in the form of—

		Tons.
1.	Alkali, or soda ash	43,500
2.	Crystals of soda	51,300
3.	Bi-carbonate of soda	7,450
4.	Caustic soda	580

The manufacture is so well understood that the local peculiarities and recent improvements will alone be noticed.

Alkali.—All the Tyne soda-ash is fully carbonated, sawdust being generally used in the furnace for this purpose, so that it contains merely a trace of hydrate of soda. The greater part of it is also refined by dissolving, settling, evaporating and calcining; thus producing an article of great whiteness and purity.

Caustic Soda.—This manufacture is, as yet, quite in its infancy in this district. In Lancashire, very large quantities are made from the "red liquors" which drain from the soda salts. These liquors always contain caustic soda, sulphuret of sodium, and common salt. In Lancashire, where a hard limestone is used for balling, the per-centage of caustic soda is large, while the sulphuret exists in small proportion, and is easily oxidized. It would seem that the London chalk which is used here, produces a lime, chemically, much less energetic, forming less caustic soda, and holding sulphur more loosely in combination. Consequently, the Tyne red liquors require a very large quantity of nitrate for their oxidation, and yield so little caustic soda that this process has been abandoned in favour of the well-known method of boiling a weak solution of alkali with lime. This has the advantage, however, of producing a richer and purer article, sometimes as strong as 74 per cent.

Improvements.—The improvements (besides such as have been already noticed) which have been introduced into the alkali trade, since the last meeting of the British Association in Newcastle, may be divided into those which have been generally adopted, and the special improvements of individual manufacturers.

1.—*Economy of Labour* has been attained by using larger furnaces, in which a workman can manipulate a larger charge with less toil, and by various other appliances, purely mechanical.

2.—*Economy of Fuel* has been largely attained by the application of the waste heat and flame from the ball furnaces to the surface evaporation of the tank or black-ash liquor. Formerly, this was evaporated in hemispherical cast-iron pans, each with a fire below.

3.—*Economy of Water and Fuel,* by the adoption of the circulating

tanks for lixiviating balls, first introduced at Glasgow, by the late Mr. Charles Tennant Dunlop. They are so arranged, as regards their connection with one another, that water runs into the tank which is most nearly exhausted, and liquor of full strength runs off the tank which has been most recently filled. The balls are always under the surface of the liquor, and thus escape the partial decomposition, and consequent formation of sulphuret, which result from the balls being subjected to successive washings and drainings off.

4.—Use of cast iron decomposing pans.

5.—Gay Lussac's process for recovering, and using again, the waste nitrous acid in the manufacture of sulphuric acid, has been adopted by several manufacturers, while others consider that the expense of the erections and of working the process, may be better applied in providing an additional amount of space in the leaden chambers.

Special Improvements.—1. The revolving furnace, for the manufacture of black-ash or soda balls, was patented by Messrs. Eliott and Russell, of St. Helen's, in 1853, and an improved method of working it was afterwards patented by Messrs. Stephenson and Williamson, of the Jarrow Chemical Works, South Shields, where three of these furnaces have been erected. Each furnace consists of a horizontal iron cylinder, 9 to 15 feet long, and 7 to 9 feet diameter, lined with 9-inch firebrick work. Two circular openings, about 2½ feet diameter in the ends, allow the fire from the furnace to pass through the cylinder and over its contents. The cylinder rests on four rollers, and is made to revolve by machinery. The charge is introduced from a hopper above, through a door in the middle of the cylinder, and the charge runs out, at the same door, when the decomposition is completed, the cylinder being stopped, for this purpose, with the door downwards.

The advantages of the revolving furnaces are:—1. No tools being required to turn over the materials, the furnace can be kept closed, and there is also a saving of manual labour, while the brick lining of the furnace lasts a very long time. 2. The mixture being kept constantly turning over and fresh surfaces exposed to the fire, the whole mass becomes gradually heated without any part becoming overheated, and the mass receives heat from the brickwork beneath, as well as from the flame and brickwork above. 3. In an ordinary black-ash furnace, while the working door is closed, the upper stratum of the charge is overheated (and the soda volatilized), and the workman finishes off the charge by mixing this overheated portion with the rest, and draws out the mass of

a proper average temperature. This has the advantage, however, of partially calcining the chalk or limestone of the mixture, and so rendering the black-ash soluble.

The black-ash first made in the revolving furnace, contained no caustic lime on account of the gradual heating of the charge, and it was impossible to exhaust it, in the lixiviating tanks, without grinding; but by the improvement introduced at the Jarrow Chemical Works, this defect is remedied. The chalk, with a portion of the coal required for the mixture, is first introduced into the furnace, and heated for about an hour, after which the sulphate of soda and the rest of the coal is introduced, the charge requiring two hours altogether for completion. By this plan, a sufficient quantity of caustic lime is produced, to render the lixiviation easy.

The furnaces, of which the dimensions are given, decompose 12 to 20 cwts. of sulphate of soda every two hours, at a cost, for labourage, of 2s. 10d. per ton, including wheeling and charging the materials.

2. In the Walker Alkali Works, the waste gas (carbonic oxide) from the blast furnaces of the adjoining iron works, is conveyed by flues to the evaporating and calcining furnaces. The advantage obtained, is not only economy of fuel, but a hot flame free from smoke and dust, and dispensing with the stoker's labour and tools. It is found very useful in regulating the bottom heat of the cast iron pan in which the salt is decomposed. The carbonic oxide is, however, found not to burn very well in the presence of muriatic acid gas.

HYPOSULPHITE OF SODA.

The manufacture of hyposulphite of soda has largely increased of late years, and we believe it was not made at all upon the Tyne in 1838. In 1854, the produce only amounted to 50 tons a year; but it has gradually risen to 400 tons per annum.

In addition to being used in photography, it is largely employed as an "anti-chlor" in paper making, and the markets of Europe and America are chiefly supplied from the Tyne.

In 1852, Mr. W. S. Losh obtained a patent for the manufacture of hyposulphite of soda from soda waste, which has been the means of greatly lessening the price, and consequently extending its application in the arts. On account of its greater stability, hyposulphite of soda has nearly superseded the use of the older salt, the sulphite of soda, as an "anti-chlor," the latter being chiefly confined to sugar refiners as a deoxidizer. Dr. Jullion has recently obtained a patent for the production

of hyposulphite of lime, to be used as an "anti-chlor," but it has not yet been introduced into commerce; the apparatus for its manufacture, in course of erection at the Jarrow Chemical Works, not being yet completed.

HYDROCHLORIC ACID.

In the decomposition of common salt, large quantities of hydrochloric acid are necessarily produced, and it is an important question for chemical manufacturers to apply the best means for its condensation. Since the visit of the Association in 1838, few branches of manufacture have received more attention, and there are few in which greater improvements have been effected, than in condensing muriatic acid gas;—this has arisen, not only on account of the necessity of preventing injury to agriculture, so that heavy claims for damage might be avoided, but also, in consequence of the commercial value attached to hydrochloric acid, in the production of bleaching powder, bi-carbonate of soda, oxichloride of lead, and other products.

The methods generally adopted in condensing, are well known, and we shall only allude to some of the improvements which have been practically applied.

The drying furnace generally used, is called an "open furnace," to which the heat of the fire is directly applied; and we believe that the greatest difficulties in the way of a perfect condensation in former times arose with the gases from this furnace. The heat required to drive off the gas from the crude sulphate of soda is very great, and when the gases arrived in the condensers, it was found difficult to absorb them, even when a very large quantity of water was used, and the muriatic acid which was thus produced, was of so low a strength that it was, commercially, almost useless.

In former years also, the draught through the condensers was always obtained by a connection with a high chimney, but in some of the manufactories, this plan is now entirely abandoned, and the whole of the vapour or gas which escapes, passes through a 12-inch pipe always open to view. At present, these gases are conducted through long flues or pipes and cooling shafts, and on entering the foot of the condensers, the heat is reduced to about 140° Fahrenheit, at which point the gases easily condense, and a strong acid is obtained at the same time.

A rather different method has been pursued, for some time, at Messrs. C. Allhusen and Co.'s Works. Instead of the heat from the fire being conducted directly on to the drying materials in the furnace, as generally done, a "close furnace" is used, in which the flame from the fire passes

over a brick arch and under the bed of the furnace, and not in immediate contact with the materials; this furnace has no connection with a chimney for its draught, and the gases, from both the pan and dryer, pass into *one* condenser. The hydrochloric acid passes off from the furnace unmixed with the smoke from the fire, and at a lower temperature than by the ordinary method, and is consequently more easily condensed, and obviates the necessity of long flues or cooling shafts.

Messrs. C. Allhusen and Sons have given us the following results of some recent experiments with this kind of furnace.

The charge of salt generally used, was 8 cwts., the moisture varied from 6 to 9 per cent., and the sulphate of soda contained from 1·75 to 2·25 per cent. of undecomposed salt.

	Salt Undecomposed	Moisture per cent.	Theoretic Weight of Acid.	Acid Obtained.	Loss per cent.
1st Experiment	1·75 ...	7·0 ...	502·0 ...	495·06 ...	1·4
2nd Do.	1·70 ...	7·0 ...	498·0 ...	489·00 ...	1·8
3rd Do.	2·25 ...	7·0 ...	498·0 ...	484·08 ...	2·6
4th Do.	1·80 ...	7·0 ...	498·0 ...	490·04 ...	1·6
5th Do.	1·70 ...	7·0 ...	498·0 ...	485·00 ...	2·6
				Average	2·0

Another instance of the care that is now bestowed in condensing, is shown in the results of some recent experiments conducted at the Walker Alkali Works, to ascertain the actual quantity of muriatic acid condensed.

The daily produce was conducted into large stone cisterns, prepared for the purpose, and the strength, depth, &c., were carefully ascertained. The salt used, was also tested daily for moisture and impurities, such as sulphates, sand, &c. The former was found to average 6·0 per cent., and the latter 1½ per cent., during six months' trial, thus leaving 92·5 per cent. Na. Cl. = 57·7 H. Cl. in 100 parts of salt used. The crude sulphate of soda produced, was also daily tested for common salt left undecomposed, which is deducted below :—

	H. Cl.	Test of Sulphates.
January, 100 parts of salt gave	58·3	2·95
February, do. do.	53·0	2·24
March, do. do.	54·2	2·26
April, do. do.	57·4	2·14
May, do. do.	58·4	2·98
June, do. do.	53·9	2·12
Average H. Cl.	55·80	2·45
H. Cl. left in sulphate of soda	1·52	
	57·32	
Loss per cent.	0·38	
	57·70	

A patent was obtained, by Mr. R. C. Clapham, in 1860, for the use of the weak acids, in the place of water in condensing, which has been successfully carried out in the above works; and it will thus be seen, that the whole of the acid produced was obtained and calculated without difficulty.

The muriatic acid is not entirely free from impurities, and, on account of its containing arsenic, iron, sulphuric acid, &c., it is not applicable to all purposes.

The total quantity of hydrochloric acid produced is about 180,000 tons per annum.

MANGANESE.

Manganese is imported from Germany and Spain, but it is chiefly from the latter country that the richest ores are now obtained, which are found in hills consisting of schistose rock, which sometimes rise to a height of 800 feet from the level of the plain; but it is also found in "pockets," and in the latter case it is quarried by picks, but gunpowder is occasionally used. The quality of the ore varies from 50 to 90 per cent. peroxide, and to obtain the richer ore, men and boys are employed to break and sort it, which is then put into sacks, and carried a distance of twenty to thirty-five miles, on mules' backs, to the ports of shipment in the Mediterranean.

The richest ores are obtained at Calànas, in the province of Huelva, thirty miles north of the ancient Roman fishing town of Huelva. We are indebted to Mr. S. D. Gething for this information, who also informs us that he imported into the Tyne, in 1857, the first cargo of Spanish manganese.

Manganese ore frequently contains peroxide of iron, copper, cobalt, titanium, &c.; but no means have hitherto been taken to separate them.

Manganese is used in the manufacture of glass, steel, and bleaching powder, and for the latter purpose, it is imported to the extent of 11,400 tons annually. Several patents have been taken out for the recovery of the manganese from the waste chloride of manganese solutions, but generally with indifferent success. The most successful is the process of the late Mr. Charles Dunlop, of Glasgow, in which the manganese is precipitated as a carbonate, and finally oxidized. This patent has been successfully worked at St. Rollox, in Glasgow, and has, to some extent, superseded the use of native manganese. Still more recently a patent has been obtained by Mr. Clapham, for the separation of the free hydrochloric acid, contained in the waste manganese solutions, and for its application in the manufacture of bleaching powder.

FRENCH LIMESTONE, LOCALLY CALLED CLIFF,

Is imported as ballast from the "Seine," and also from the coast of France, to the extent of about 14,000 tons annually. It forms part of the upper chalk bed in the secondary deposits, and is nearly pure carbonate of lime, and although very like chalk in its appearance, differs from it, to some extent, in being compact, harder, and less capable of retaining water. It is always used in this locality, in preference to other limestones, in making bleaching powder.

BLEACHING POWDER.

The process pursued in the manufacture of bleaching powder has entirely changed since 1838, and the quantity made has far more than doubled.

At that time it was made by the decomposition of manganese and common salt, with sulphuric acid, which was a rather costly process, and the price was about £28 per ton. It is now manufactured from what was, at one time, the waste muriatic acid, referred to above, and the price has been reduced to one-third.

During the last few years, the demand for bleaching powder has been increased, partly on account of the extensive use of Esparto grass from Spain in the manufacture of paper, which has been found to require a large quantity of chemicals to bleach it. The quantity of bleaching powder now made is 11,200 tons per annum.

SOAP.

The first soapery in this locality was begun by Messrs. Lamb and Waldie, about the year 1770, at the Westgate, whence it was removed to the Close. The works were purchased by Mr. Thomas Doubleday in 1775, and continued under the firm of Doubleday and Easterby until the year 1841. Other manufactories were built in Sandgate and at the Ouseburn, but they have been abandoned.

Very little hard soap was made until the end of the last century; Castile soap alone being used. Up to 1770, soft soap was chiefly used for both domestic and manufacturing purposes.

The chief improvements introduced have been the use of palm oil, bleached by Watt's process, and the manufacture of the ley by boiling the alkali with the lime, instead of the so-called "*cold process.*"

The total quantity now manufactured exceeds 6000 tons per annum.

The prices of various materials at the present time are as follow:—

Tallow, 1st sort T.C.	43s. 6d.	per cwt.
Fine American resin	36s. to 39s. 0d.	„
Best yellow soap	33s. to 35s. 0d.	„
Best mottled do.	33s. 0d.	„

PRUSSIATE OF POTASH.

The first attempt to manufacture any compound of cyanogen in this district, was made in the beginning of the last century, by a Jew, in Oakwellgate, Gateshead. He afterwards removed his apparatus to Corbridge, but failing in producing a saleable article, he discontinued the operation, which was taken up by a Mr. Simpson, who ultimately succeeded in perfecting the process in works erected at Elswick. Mr. Simpson manufactured Prussian and other kinds of blue colours; and, at his death, the manufacture was removed to Heworth, where the Messrs. Bramwell have carried on the works since 1758.

Prussian blue was the only form in which the cyanogen was produced, from which prussiate of potash was afterwards manufactured. This salt was not known in commerce in a crystallized form, however, till about the year 1825, when the price was 5s. per lb., which has now fallen to 11½d.

Mr. Bramwell has introduced various improvements in the manufacture of this salt, employing close pots, in which the fused materials are worked by machinery, and in substituting sulphate of potash for the more expensive potashes; but, notwithstanding the application of every chemical and mechanical appliance, and the low prices at which the prussiate of potash is sold, the demand has fallen off; and at present only two tons of yellow prussiate, and three-quarters of a ton of red prussiate, are manufactured weekly. The decline in this trade has arisen, partly from the American civil war, and partly from the introduction of the aniline colours.

The celebrated attempt, in 1844, to produce cyanogen from the nitrogen of the air, was made at these works, and although the efforts of Mr. Bramwell and his friends were perfectly successful in a chemical point of view, these gentlemen were induced to abandon the process as a manufacturing operation.

ALUM.

The first alum works established in England were erected at Guisbro'

in 1460, by Sir Thomas Challoner, who brought over a workman from France to carry out the, then secret, process; the monopoly of this trade being in the hands of the Pope.

The works were subsequently decreed to be a royal mine, and passed into the possession of the Crown. They were afterwards farmed to Sir Paul Pinder, at a rental of £15,000 per annum. He employed about 800 persons, and made large profits, his monopoly enabling him to keep up the price to £26 per ton.

The Long Parliament restored the mines to the original owners, and at the Restoration, not less than five manufactories were in operation.

The process is well known, but potash alum (formerly the only alum made) is now produced at the Loftus works, all the other manufacturers employing the cheaper sulphate of ammonia. From the mother liquors, large quantities of an impure sulphate of magnesia are obtained, which are partly refined, and partly consumed as a manure, mixed with other substances.

Alum and sulphate of alumina are also made from sulphuric acid and clay, or shale, but the quantities are not very large.

The quantities produced annually, are as follow:—

Alum, &c.	4000 Tons
Rough Epsoms	1800 „

Some improvements in the details have been introduced to economize labour and save materials. The percipitation of the iron from the aluminous liquors, by means of prussiate of iron, was first employed here by Messrs. Lee and Co.; and the Guisbro' Alum Company have introduced an aluminous cake containing sulphate of magnesia, which has been found to answer very well in dyeing certain colours, as browns, blacks, &c., and in the manufacture of all kinds of coarse papers.

EPSOM SALTS.

The abundant supply of dolomite, on the coast at Marsden, three miles south of the Tyne, and at other places in the county of Durham, has for many years sustained the manufacture of sulphate of magnesia in this district. The mineral is a tolerably pure double carbonate of lime and magnesia, containing about 21 per cent. of magnesia. Mr. Clapham gives the following analysis of this mineral:—

Silica	10·00
Alumina	1·60
Oxide iron	0·50
Carbonate magnesia	35·33
Carbonate lime	52·50

The process formerly employed, was to calcine the limestone, and wash it repeatedly with water; by which, however, the lime is only imperfectly removed, the residue being dissolved in acid and crystallized.

The principal source of sulphate of magnesia, for many years past, has been the rough Epsoms, obtained from the residual mother liquors of the Yorkshire Alum Works. In these salts, protoxide of iron replaces a variable proportion of magnesia, forming a double salt, and containing also free sulphuric acid.

Analysis of rough Epsom salts:—

	Richardson.	Jarrow Chemical Co.		
Sulphuric acid	32·26	32·60	33·60	32·24
Magnesia	15·35	10·25	7·02	8·60
Protoxide of iron	1·73	8·55	6·75	11·25
Oxides of nickel and cobalt	0·12			
Lime	0·09			
Alumina	1·33			
Potash	0·83			
Water	48·29			

These salts were formerly mixed with washed magnesian lime, and then calcined, in order to peroxidize the iron. It is found, however (as first suggested by Dr. Richardson), that calcination is unnecessary when the solution is sufficiently diluted, and when space is provided in the precipitating tank for the bulky precipitate of protoxide of iron, which is formed by the gradual addition of magnesian lime.

This is probably the only chemical manufacture of the district—with the exception of prussiate of potash—which has greatly fallen off in extent, a more rational system of medicine having diminished the use of purgatives and reduced the demand for Epsom salts to about one-third of what it was 20 years ago. The annual production is still 1500 tons, two-thirds of which are made from the rough salts.

CARBONATE OF MAGNESIA.

This compound has long been produced in this district, where it was formerly, and is still, to a limited extent manufactured from the mother liquors of the salt pans, known as *bittern*, to which carbonate of soda is added to precipitate the magnesia in the form of carbonate.

This old plan has been largely superseded by the elegant process of the late Mr. H. L. Pattinson, which consists in submitting calcined magnesian limestone to the action of carbonic acid and water under pressure. The magnesia dissolves out as bi-carbonate of magnesia, from

which the neutral carbonate of magnesia is precipitated by the application of heat.

The quantity manufactured is said to be about 250 tons per annum.

SUPERPHOSPHATE OF LIME.

The manufacture of this article was commenced at Blaydon in 1844 by Dr. Richardson, soon after the publication of Liebig's celebrated Report on Agricultural Chemistry.

Various materials are employed as the source of phosphate of lime, viz., bones; bone ashes from South America; exhausted animal charcoal from the sugar refineries; coprolites from Suffolk and Cambridgeshire; phosphorite from Spain; Sombrero guano, &c. Improvements have been introduced in the manner of mixing the acid with these substances, in drying, and in the riddling of the superphosphate.

The quantity produced amounts to between 15,000 and 16,000 tons per annum.

PEARL HARDENER.

This article has only recently been manufactured here, and its introduction is due to Dr. Jullion, who has applied it to the hardening of paper. It is produced by precipitating hydrated sulphate of lime from a perfectly pure solution of chloride of calcium, by means of sulphuric acid. Great care is taken in its preparation, and it is being generally introduced among the manufacturers of paper.

The quantity made is said to be about 2000 tons per annum.

SULPHATE OF IRON.

The first manufactory for the production of green copperas in England, was founded about the year 1579, when one Matthew Falconar, a Brabanter, "did try and draw very good brimstone and copperas out of certain stones gathered in great plenty on the shore near unto Minster, in the Isle of Sheppey."

Mr. Thomas Delaval commenced to manufacture copperas at Hartley about the year 1748, but he subsequently sold the manufactory to his brother, Lord Delaval, and by an Act of Parliament, 11 George III., in 1771, power was given to Sir Francis Blake Delaval to grant to Sir John Hussey Delaval, in fee simple, all the copperas works then and there existing, which may enable us to form some idea of the importance attached to this manufacture at that period.

The late Mr. Barnes and Alderman Forster erected the first copperas works on the Tyne at Walker, in 1798, which are still in operation.

The quantity at present manufactured is about 2000 tons per annum, and the process is still the same; but Mr. Thomas Barnes has applied the refuse crystals to a novel purpose. This refuse was, and is generally, thrown away, but Mr. Barnes uses it as a manure on the thin soil of his farm, which lies on the Magnesian-limestone. He finds that the depth of the soil is gradually increasing by the disintegration of the rock, and that the more he uses, the more satisfactory are the results. The beneficial effect of the copperas is, doubtless, partly due to the natural decomposition of carbonate of lime with the sulphate of iron, and partly to the action of the peroxide of iron on the organic matter of the soil; a supply of oxygen is provided in a solid form by this hydrated oxide of iron, which is continuously renovated.

Mr. Barnes, who has kindly furnished the above information, has also given the annexed diagram to show the fluctuations of price to which this trade has been subjected during the present century.

VENETIAN RED.

The manufacture of this article has long been carried on in this neighbourhood, and is noticed here as it is so closely related to green copperas.

It is made by calcining a mixture of copperas, and some native hydrated oxide of iron, chalk, and gypsum. The calcined mass is levigated and dried. About 4000 tons per annum are manufactured on the Tyne, and the price varies from £4 10s. to £5 per ton.

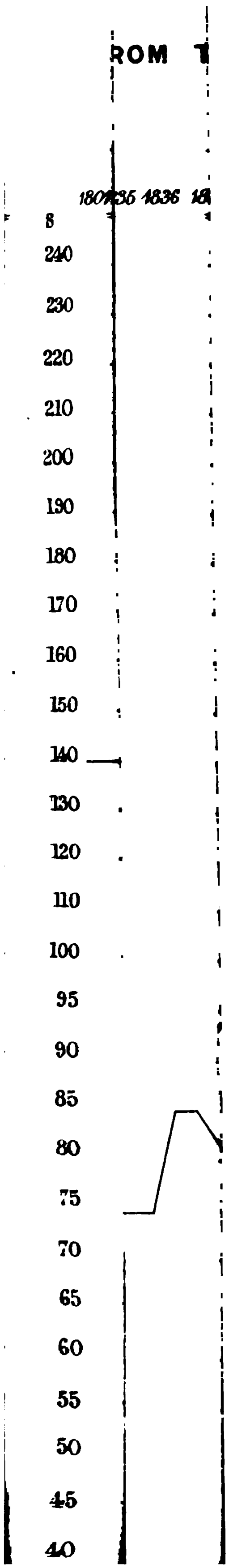
SULPHATE OF COPPER.

This salt was formerly produced by roasting old copper in a reverberatory furnace, and then dissolving the oxide in sulphuric acid; but it is now obtained in carrying out Longmard's process for decomposing common salt by means of cupreous pyrites. The quantity made is about 100 tons per annum, which is all produced at the works of Messrs. J. and W. Allen.

RESIN SIZE.

This article is manufactured according to a patent obtained by Mr. W. S. Losh, and is intended to produce a size suitable for paper makers, and to supersede the old size in ordinary use, which consists of alum, resin, and soda ash.

Its manufacture has, however, been only partially developed, and not more than 100 tons yearly is produced; but a new and cheap size, which


ROM T
1807 1835 1836 18
8
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
95
90
85
80
75
70
65
60
55
50
45
40

can be prepared ready for the use of the paper trade, is, we think a step in the right direction, and the theory of the sizing of paper is a field still open to chemists.

LAMP BLACK.

The manufacture of lamp black, we believe, is peculiar to this locality, and it is produced from bituminous coals. These coals are slowly burnt, at a dull heat, and with as small a supply of air as possible. The smoke is conducted into brick chambers, into which a jet of steam or water is passed, to assist in the better deposition of the lamp black. The quantity made is about 1200 tons per annum.

GREASE.

This is another product of local importance, and is made to the extent of 2800 tons per annum. It is chiefly made in connection with the distillation of resin, and, in a locality like Newcastle, surrounded by extensive collieries and works, the consumption is always increasing.

Since the American war, the price has been much affected, and we are told, has advanced from £8 or £9 per ton to £22 per ton.

CEMENT.

The manufacture of this material, on a large scale, in this district, is of comparatively recent origin. A small quantity of cement has long been made on the Yorkshire coast, near Whitby, where a peculiar mineral is found in the alum shale, called *cement stone*. This mineral has been analysed by Dr. Richardson, who found it to contain—

Clay, insoluble in acids		18·41
Consisting of silicia	12·24	
alumina	6·17	
Alumina, soluble in acids		6·89
Oxide of iron		0·54
Lime		37·68
Magnesia		5·20
Soda and potash		traces
Organic matter		1·48
Carbonic acid and water		29·62
		99·77

About 20 cwts. of this mineral is found in every 60 tons of shale; and the greater proportion is sent to Hull, where it is manufactured into a cement sold under the name of *Mulgrave Cement.*

The mineral is burnt in small open kilns, and afterwards ground to a fine powder.

The production of cement on a large manufacturing scale dates from the establishment of the works of Messrs. I. C. Johnson and Co., in 1856. This firm manufactures—

Portland Cement,
Roman, ditto,
Keene's Marble, do.,
Plaster of Paris,

and have recently introduced improved machinery for the more perfect levigation of the raw materials, by which the subsequent chemical action is much facilitated.

Portland cement is very extensively used in this country, in France and Germany, for dock works, basins, fortifications, and for fronting houses in imitation of stone. It is also used for coating the inside of all first-class iron ships. The rivets are carefully coated, and are thus protected from the corrosive action of the bilge water. It has been found of equal service in sugar-carrying vessels, where the leakage of the molasses exercises a very corroding action on the iron.

Roman cement is prepared by calcining septaria in open kilns, and afterwards grinding the burnt material in horizontal stones. It is used either alone or mixed with an equal volume of sharp sand.

Keene's marble cement is made by soaking calcined gypsum in a solution of alum, and then re-calcining the mass at a dull red heat. This re-calcined material is then ground and sifted. It is only used for internal work, such as floors, skirtings, walls, &c. It is largely employed in London, in churches and clubhouses. It rapidly dries after being applied, and may be papered or painted in two days. When dry, it is so hard that a nail cannot be driven into it. Two qualities are made, one of which can be polished in imitation of marble, while the other is used as a ground for painting. When different colours are introduced, a superior scagliola is formed.

The quantities manufactured per annum, are as follow :—

		Tons.		Casks.
Portland Cement	... ...	10,000	in	50,000
Roman, do.	... ...	850	„	2,450
Keene's do.	... ...	50	„	350
Plaster of Paris	... ...	200	„	2,000

and the present prices are—

Portland Cement,	8s. 6d.	per cask of	430lbs.
Roman do.	7s. 6d.	do.	336lbs.
Keene's do.	14s. 0d.	do.	336lbs.
Plaster of Paris,	30s. 0d.	per ton.	

CHEMICAL PRODUCTS OF GAS WORKS.

The quantity of coal used for the manufacture of gas on the three northern rivers, the Tyne, Wear, and Tees, amounts to about 100,000 tons.

The products obtained are as follow:—

875,000,000 cubic feet of gas	£113,000
53,000 tons of coke	10,000
23,800 gallons crude naphtha	2,800
309,000 gallons creosote oil	1,250
3560 tons of pitch	3,130
600 tons of sulphate ammonia ...	9,000
	£139,180

The sulphate of ammonia is manufactured direct from the gas water in the following manner:—a large cylindrical boiler is filled two-thirds full with the gas liquor, and gently boiled. The gaseous products and steam are conducted into a mother liquor from a previous operation, which is kept slightly acid. When no more ammonia comes over, a quantity of milk of lime is added to the boiler, and a strong heat applied, until the colouring matters cease to be disengaged. The gaseous products are collected as before, and the colouring matters are skimmed off from the surface of the liquor. The boiling is then moderated, and during the whole operation a stream of acid is supplied to the cistern. The sulphate of ammonia salts out and is fished up into baskets to drain, when it is ready for the market.

QUANTITIES AND PRICES.

Raw Materials.	Tons.	Price. £	s.	d.	Value. £	s.	d.
Sulphur	(included as Pyrites)						
Pyrites	72,800	1	10	0	109,200	0	0
	Copper value not included.						
Salt	90,000	0	15	0	67,500	0	0
Nitrate of soda	2,500	14	15	0	36,875	0	0
Chalk	144,000	0	2	6	18,000	0	0
Coals	323,000	0	3	9	60,562	10	0
Manganese	11,400	4	0	0	45,600	0	0
Rough Epsom salts	1,500	2	5	0	3,375	0	0
Magnesian-limestone	700	0	3	6	122	10	0
French limestone	14,000	0	4	6	3,150	0	0

QUANTITIES AND PRICES.

Finished Products.	Tons.	Price. £ s. d.	Value. £	s.	d.
Alkali	43,500	8 10 0	369,750	0	0
Crystals of soda	51,300	4 15 0	243,675	0	0
Bi-carbonate of soda	7,450	12 0 0	89,400	0	0
Caustic soda	580	18 0 0	10,440	0	0
Hyposulphite of soda	400	25 0 0	10,000	0	0
Oil of vitriol	6,440	6 0 0	38,640	0	0
Epsom salts	1,500	7 5 0	10,875	0	0
Bleaching powder	11,200	9 0 0	100,800	0	0
Soap	6,000	34 0 0	204,000	0	0
Yellow prussiate of potash	105	1s. per lb.	11,760	0	0
Red ditto	40	2s. 6d. „	11,200	0	0
Alum	4,000	7 0 0	28,000	0	0
Carbonate of magnesia	250	30 0 0	7,500	0	0
Superphosphate of lime	15,000	5 0 0	75,000	0	0
Pearl hardener	2,000	10 0 0	20,000	0	0
Sulphate of iron	2,000	3 0 0	6,000	0	0
Venetian red	4,000	5 0 0	20,000	0	0
Sulphate of copper	100	35 0 0	3,500	0	0
Resin size	100	7 0 0	700	0	0
Lamp black	1,200	7 0 0	8,400	0	0
Grease	2,800	8 0 0	22,400	0	0
Cements	12,000	2 0 0	24,000	0	0
Chemical products of gas works	„	„	139,180	0	0
	171,955		£1,455,220	0	0

APPENDICES.

No. I.—SALT.

The recent, interesting, and important discovery of a bed of rock-salt at Middlesborough, has attracted great attention, and the following information is taken from the paper of Mr. Marley, read before the British Association.

Messrs. Bolckow and Vaughan being anxious to obtain a supply of fresh water for their iron works, commenced, about four years ago, to sink a shaft for this purpose. This well did not answer their expectations, and a very large bore-hole was put down from the bottom of the shaft. The strata passed through are in the Upper-new-red-sandstone, or the same as those in which the Cheshire rock-salt is found.

The following is an account of the strata sunk and bored through. Sinking was commenced on July 4, 1859 :—

No.	Fm.	Ft.	In.
1—Made ground (slag, chalk, &c.)...	1	5	0
2—Dry slime or river mud	1	2	0
3—Sand with water	1	4	0
4—Hard clay (dry)	1	4	0
5—Red sand with a little water	0	1	0
6—Loamy sand with a little water	0	3	0
7—Hard clay (dry)	2	3	0
8—Rock, mixed with clay and water	1	5	0
9—Rock, mixed with clay (dry)	0	1	0
10—Rock, mixed with gypsum (dry)	1	0	0
11—Gypsum with water	0	2	0
12—Red-sandstone with small veins of gypsum and water	9	1	0
13—Gypsum rock (dry)	1	0	0
14—Brown shale with water...	0	1	0
15—Red-sandstone	0	4	0
16— Do. with small veins of gypsum and water	2	0	0
17—Blue poststone with water at bottom	0	3	0
18—Red-sandstone with water	3	1	0
Bottom of sinking	29	4	0
19—Red-sandstone	72	5	4
20—Red and White-sandstone	0	1	6
21—Red-sandstone	85	5	7
22— Do. and clay	0	1	0
23—Red-sandstone	8	4	3
24— Do. and clay	1	3	0
Carried forward ...	149	0	8

	Fm.	Ft.	In.
Brought forward ...	...149	0	8
25—Red-sandstone	11	0	5
26—Strong clay	0	2	9
27—Red-sandstone and clay	0	1	6
28— Do.	4	3	5
29— Do. and clay	1	3	0
30— Do. with a vein of blue rock 1½ thick at 1005 feet	8	1	4
31—Red and Blue-sandstone	0	1	5
32—Red-sandstone	1	0	0
33— Do. and thin veins of gypsum ...	0	1	5
34— Do. Do. ...	6	3	8
35—Red-sandstone, blue clay, and gypsum ...	0	1	2
36— Do. with veins of gypsum ...	14	3	3
37—Gypsum	0	3	2
38—White stone	0	0	8
39—Limestone	0	2	8
40—Blue rock	0	0	2
41—Blue clay	0	0	2
42—Hard blue and red rock	0	0	10
43—White stone	0	2	7
44—Dark red rock	0	1	2
45—Dark red rock, rather salt	0	6	7
46—Salt rock, rather dark (1)	2	0	7
47— Do. very dark (2)	0	4	1
48— Do. very light (3)	0	3	6
49— Do. rather dark (4)	4	3	4
50— Do. very light (5)	7	1	6
51— Do. rather light (6)	1	3	0
52—Limestone	0	1	0
53—Conglomerate. This rock resembles limestone, and contains a great quantity of salt	1	0	4
Total	218	5	4

The six items = 100 feet of salt (but not yet through) equal to 1306 feet.

The following analysis of a sample of the rock-salt, was given by Mr. Marley :—

Chloride of sodium	96·63	per cent.
Sulphate of lime	3·09	„
Sulphate of magnesia	0·08	„
Sulphate of soda	0·10	„
Silica	0·06	„
Oxide of iron	trace	„
Moisture	0·04	„
	100·00	

FIG. 1.

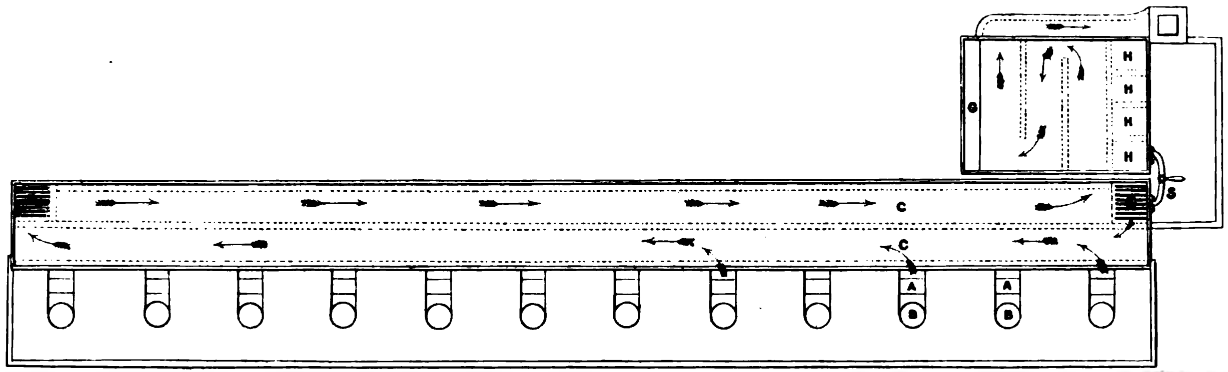


FIG. 2.

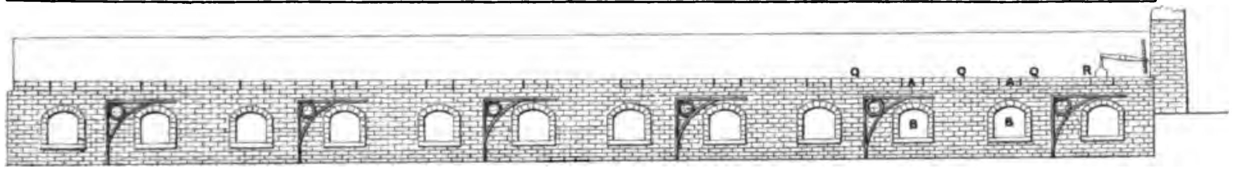


FIG. 3.

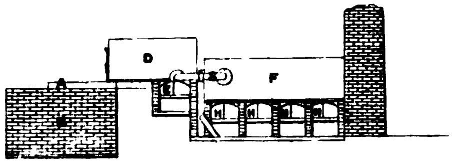
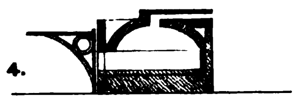


FIG. 4.



It is impossible to overrate the importance of this discovery to this district, where the consumption exceeds 100,000 tons per annum.

The production of salt in this country is upwards of 1,500,000 tons per annum, of which about 120,000 tons is rock-salt; and when the peculiar advantages of this locality are considered, the opportunity of dissolving the rock-salt in sea-water, the numerous sources of waste heat and cheap fuel to evaporate the brine liquors, and the low rate of freights to all parts of the east and south-east coasts of Great Britain and the Baltic, whither 150,000 tons of salt are exported, it is obvious that a large share of this trade must fall to this district.

Shields Salt.—We have already alluded to the salt made at Shields in former times, when, as late as 1802, all the ground between Stone Quay and Milldam was covered with salt pans.

During the above period, the white salt was obtained exclusively from sea-water, and it required 50 cwts. of coals to extract 20 cwts. of salt. This enormous consumption of fuel was then not a serious item of expense, as there was no demand for the small coals, which were usually burnt near the collieries, forming the fiery pit-heaps which characterized the neighbourhood of Newcastle in those days. The small coal only cost the salt makers the expense of conveying it to their works by river craft. The demand for this small coal for coke-burning, and for the general manufactures of the district, has so enhanced its value, that it no longer pays to extract salt from sea-water.

Shields salt is still made, but not exclusively from sea-water. Cheshire or Irish rock-salt is dissolved in sea-water, and the brine is evaporated by the waste heat of coke ovens and whiting furnaces. It is said that 20 tons of Shields salt are sent weekly to Newcastle, where it brings twice the price of Cheshire or Droitwich salt. It is preferred to all others for curing purposes, and probably owes its superiority to the presence of the chloride of magnesium, derived from the sea-water. Mr. Wilkinson, to whom we are indebted for this information, informs us that when the pitmen kill their pigs, they will cure with nothing but Shields salt, and he states that it never fails, which cannot be affirmed of the other kinds of salt sold for this purpose.

We give the details of Mr. Wilkinson's plan for employing the waste heat of coke ovens, which has been very successful, and is now in operation on the Tyne.

This process is illustrated in the accompanying diagrams, in which fig. 1 represents a plan view, a range of twelve coke ovens, with an evaporating and crystallizing pan (which he uses for the manufacture of common salt) attached, and fig. 2 is an elevation of the same range. AA, are the flues leading from the ovens BB, and connected with the flue C (shown by dots in fig. 1), which runs underneath the evaporating pan D; EE, are two auxiliary furnaces, for keeping up the temperature of the flue C, and burning the combustible gases which are given off from the coke ovens; F is a crystallizing pan, and G, a receptacle or well into which the salt is collected; HHHH, are furnaces attached to the crystallizing pan, and intended to regulate the concentration of the liquor, as circumstances may require. Fig. 3 represents an end elevation of the range of ovens and pans shown at figs. 1 and 2; and fig. 4 is a longitudinal section of one of these ovens.

The mode of operation pursued in the manufacture of the common salt is as

follows :—The evaporating pan D is supplied with salt water from a reservoir or other convenient source, and in order to apply the heat equally to the pan D, each alternate oven is charged at proper intervals of time, dividing the range into three sections of four ovens each, and charging one section per day. By this means, the combustible gases liberated from each newly charged oven, are brought into contact with the heated flue of the next oven, which is in a more advanced stage of the process, and by introducing a proper quantity of air to support combustion in the circulating flue, nearly all the combustible gases are consumed ; QQ, are apertures to introduce air to support combustion at any point, which may be found necessary in the circulating flue. Each of the ovens is provided with a damper, R, by which the communication with the circulating flue C may be stopped at pleasure. The two auxiliary furnaces EE are used to keep up the temperature of the circulating flue, and at the same time to control the evaporating pan. When the liquor or brine is sufficiently concentrated in the evaporating pan, a portion is run into the crystallizing pan by means of the connecting pipes S, figs. 1 and 3, and the liquor is purified before precipitating or crystallizing the salt, by a further concentration of the liquor by the furnaces, HH.

No. II.—SULPHUR ORES.

Mr. Pattinson read an interesting paper on these ores, from which we extract the following table of analyses of different samples sent to the Tyne :—

	1	2	3	4	5	6	7
Sulphur	44·60	49·30	45·01	45·60	46·50	44·20	38·10
Iron	38·70	41·41	39·68	38·22	39·22	40·52	31·44
Copper	3·80	5·81	„	„	1·80	0·90	trace
Lead	0·58	0·66	0·37	0·64	„	1·50	„
Zinc	0·30	trace	1·80	6·00	1·18	3·51	„
Thallium	trace	trace	trace	trace	„	„	„
Lime	0·14	0·14	0·25	0·11	2·10	0·24	4·96
Magnesia	trace	trace	„	„	0·01	„	0·33
Carb. Acid	„	„	„	„	1·65	„	5·11
Arsenic	0·26	0·31	trace	trace	„	0·33	trace
Oxygen	0·23	0·25	0·42	0·37	0·45	0·25	0·31
Coal and loss	„	„	„	„	„	„	14·45
Gangue	11·10	2·00	12·23	8·70	9·08	8·80	1·40
Moisture	0·17	0·05	0·25	0·36	0·17	0·90	0·90
	99·88	99·93	99·91	100·30	100·16	100·34	100·3

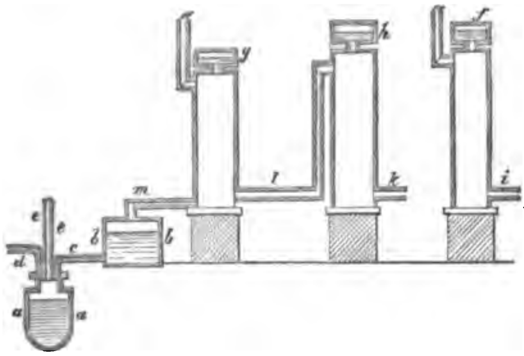
The numbers attached to each analysis, refer to the following ores, of which Mr. Pattinson gives an estimate of their consumption in this district :—

		Tons.
Nos. 1 and 2	Spanish pyrites ...	... 30,000 per an.
„ 3	Belgian do.	... 12,000 „
„ 4	Westphalian do.	... 6,000 „
„ 5	Norwegian do.	... 6,000 „
„ 6	Irish do.	... 4,000 „
„ 7	Coal brasses do.	... 7,000 „

No. III.—CONDENSATION OF HYDROCHLORIC ACID.

In the Report, reference is made to the plans for condensing this acid, which have been so successfully carried into operation at the works of the Walker Alkali Company and of Messrs. Allhusen and Sons.

The following description contains an account of the plan of Mr. Clapham, which has been adopted at Walker. The object of this plan is to save the weak acid which is obtained from the drying beds. Mr. Clapham cools this weak acid, and then employs it, instead of water, for the No. 1 condenser. The apparatus is similar to that adopted in Gay Lussac's process. It consists of a series of cooling cisterns, made of Caithness flags, secured with suitable cement, from whence the weak acid is conveyed, by a gutta-percha pipe, to an egg-shaped metal vessel, lined with gutta-percha. An ordinary air-pump is attached to this vessel, by which the contents are forced up to a cistern on the top of No. 1 condenser.



The woodcut represents a sectional elevation of the arrangements, in which *a* is the metal vessel lined with gutta-percha, receiving the weak acid from a cistern *b* by the pipe *c*; *d* is a pipe leading from the air-pump to the vessel *a*; *e* is a pipe conveying the weak acid, forced from the vessel *a* to the cistern *f*, at the top of condenser No. 1. The condensers Nos. 1, 2, and 3, are of the usual construction, Nos. 2 and 3 being surmounted by water cisterns *g* and *h*. The pipe leading from the decomposing pans to the condenser No. 1 is shown at *i*; *k* is a pipe passing from No. 2 condenser to the drying furnace; *l* is a pipe to convey the waste gas from No. 2 to No. 3 condenser; and *m* is a pipe for conveying the weak acid to the cistern *b*.

Water is supplied only to No. 3 condenser, and the weak acid from this condenser is supplied to Nos. 1 and 2 condensers, from which acid of an average strength of 25° F. is obtained.

Messrs. Allhusen's arrangements are shown in the accompanying woodcuts, for which we are indebted to the liberality of these gentlemen; and Mr. H. C. Allhusen has kindly furnished us with the following explanatory remarks. The woodcuts represent:—

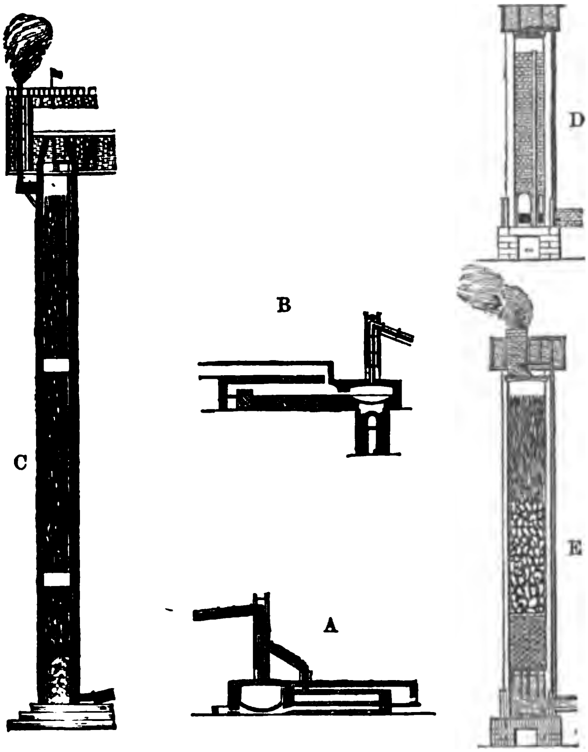
A. A close furnace.

B. A reverberatory furnace.

C. The strong acid condenser.

D and E. The weak acid or "drier" condensers.

The close furnace is attached to one condenser only, C; the pan and drier having no connection whatever with the chimney.



The pan of the reverberatory furnace is attached to a strong acid condenser, similar in every respect to C, but its drier is connected with the weak acid condenser D, the draught through the latter being obtained by means of a chimney. The condensation is quite as perfect in this, as in the preceding arrangement.

The wear and tear of the close furnace is much greater, and this cause, together with the great draught required, renders the reverberatory furnace preferable.

One of the reverberatory furnaces, at Messrs. Allhusen's works, has its drier attached to a weak acid condenser E, which, like the strong acid condenser, is high enough to create its own draught, and there is no connection with the chimney.

These woodcuts must be examined in connection with the description in the Report, in which details are given of the admirable manner in which they condense the hydrochloric acid.

IV.—DECOMPOSITION OF COMMON SALT.

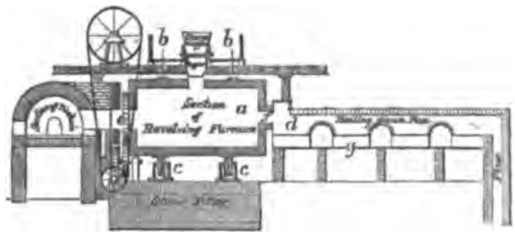
In making sulphate ash, white salt has always been employed, as it has been impossible to effect a complete decomposition of rock-salt. This latter material is much cheaper than white salt, and contains more chloride of sodium. Messrs. Stevenson and Richardson have recently patented a plan for substituting rock for white salt in the decomposing process, which promises to become of value. Their

plan consists in grinding and heating the rock-salt, previous to the addition of the sulphuric acid, and from the experiments already made, an excellent sulphate of soda has been obtained.

No. V.—REVOLVING FURNACE.

This remarkable invention only requires to be better known to find many other applications, besides that of balling sulphate of soda, coal, and chalk.

The accompanying woodcut represents a section of the furnace in use at the Jarrow Chemical Works.



The arrangements consist of an iron cylinder *a*, lined with fire-bricks, and two cast-iron rings, *bb*, are attached to the exterior of the cylinder. These rings rest and run on strong iron wheels, *cc*, which are carried by proper bearings. A pair of pulleys, and a system of wheels, are employed to give a revolving motion to the cylinder. The furnace is shown at *d*, whence the flame passes into and through the cylinder by openings at each end, *e f*, and afterwards, over the liquors in the evaporating pan *g*, to the chimney.

The cylinder is charged through an opening *h*, which is brought under the hopper filled with the materials. The progress of the operation is watched through an opening at the end, and when it is complete, the opening is uncovered, its position is reversed, and the charge falls into a number of iron waggons chained together, and brought in succession under the opening.

The successful working of this revolving furnace is due to the improvements introduced by Messrs. Stevenson and Williamson. They charge the cylinder fresh with chalk and coal, which are raised to a high temperature, and then the sulphate of soda is added. The total charge weighs two tons, which is worked off in two hours.

No. VI.—BLEACHING POWDER.

A recent improvement, which is being tried at the Walker Chemical Works, promises to be of considerable value.

This process consists in superheating the steam by Green's apparatus, before it is admitted into the stills, by which the dilution of the acid is lessened, and the temperature of the materials is increased.

No. VII.—EPSOM SALTS.

The supply of rough Epsoms has recently been increased by the produce of the salt-gardens in the South of France. The utilization of the mother-liquors from these works, is now accomplished by processes which Mons. Balard has introduced.

He obtains not only sulphate of magnesia, but also sulphate and muriate of potash and sulphate of soda; and as his plans could be adopted in this district, we venture to give the following abstract of his operations, for which we are indebted to the kindness of Mr. A. F. Marreco :—

The utilization of these mother-liquors has completely altered the relative importance of the salt and the remaining products, large establishments being now erected, chiefly for the sake of the mothers which are obtained.

Both the methods employed in working up these liquors depend, chiefly, on the action of cold; the old process relying on the cheap but uncertain colds of winter, while the newer, employing the refrigerator of Carré, worked by liquefied ammoniacal gas, obtains a far more regular and manageable result, independent of seasons.

As conducted on the most approved plan, by the Southern Salt Company, at Berre (Bouches da Rhône), the natural process yields—

1. "Sels mixtes," from which sulphate of soda is prepared.

2. Residuary liquor, containing all the potash, which may be extracted by two different methods.

In concentrating at summer heat, from 32·5° to 35° B. (1·272 to 1·299), the liquors deposit a salt containing about equal proportions of hydrated sulphate of magnesia and common salt. This is removed, drained in "camelles,"* and redissolved, so as to obtain a liquor marking 31–32° B. (1·25–1·26), in which the salts shall be in the ratio of 1 equivalent sulphate to 1¼ equivalent of salt.† Such a solution deposits sulphate of soda on very slight cooling, the excess of salt greatly contributing to ensure this result by diminishing the solubility of the sulphate. The solution is preserved in clay basins, lined with concrete, filled to a depth of about 18 feet, to lessen the chance of dilution by rain, which interferes with the success of the crystallization. When the atmospheric temperature falls sufficiently low, the liquid is run out and exposed in layers of 4 to 8 inches in depth. The deposition of sulphate commences even at 45° Fahr., and at 28° four-fifths of the theoretical quantity is deposited in the hydrated form. In the morning, the liquid is run off from the sulphate formed during the night, which is drained in "camelles" previous to desiccation. When the production of "sels mixtes" is properly managed, the mothers at 35° (1·299) contain all the potash of the sea-water. In small works, they are evaporated, yielding a complex mixture of sulphate of magnesia, double sulphate of magnesia and potash, chloride of potassium, and double chloride of magnesium and potassium, containing on an average 11 or 12 per cent. of potash. Treated with milk of lime, the mass dried and ignited, they furnish a solution from which chloride of potassium may be crystallized; but as their sulphuric acid is thus wasted, it is found more advantageous, where the size of the works is sufficient, to employ the process next to be described. In the larger works the mothers of 35° (1·299), obtained in summer, are preserved and exposed in autumn to a temperature of about 41° Fahr., at which they deposit hydrated sulphate of magnesia, a large portion of which is consumed in preparing sulphate of

* Large heaps with inclined sides, containing some thousands of cubic metres.

† It would seem that some sulphate of magnesia must be added, as the salt in the "sels mixtes" considerably exceeds this ratio.

soda by the method just described, which utilizes samples of salt contaminated with mechanical impurities. After this crystallization, the liquors are returned to the reservoirs, and kept for the next summer's work. By concentration they then yield the salt (KCl, 2 Mg Cl, 12 HO), mixed with a little common salt. The mothers from this salt, are rejected as worthless. The double chloride is dissolved in warm water in a boiler; the chloride of potassium separates on cooling, and is purified by re-crystallization.

The weak points of this natural system are—

1. The difficulty of regulating exactly the temperature. For if, in treating the mother liquor of 35°, it fall notably below 41° F., the sulphate of magnesia is contaminated by double chloride, causing a loss of potash and injuring the purity of the sulphate.

2. The absorbent nature of the soil on which the crystallizations are conducted, which entails such loss of fluid, that 10 to 20 per cent. only of the total potash contained in the sea-water, is actually obtained.

The artificial method starts with liquors marking only 28° B (1·225), from which are obtained, at the works of the C.. Meole, sulphate of soda, fine salt (sel fin-fin), chloride of potassium, chloride of magnesium, and bromine.

The liquors at 28° are conducted to the Carré machine, into the cooler of which they enter along with a small stream of fresh water, intended to prevent the deposition of hydrated common salt. They leave it, at a little below zero (Fahr.), after depositing 85 per cent. of their sulphuric acid, as sulphate of soda, with ten equivalents of water. The sulphate is valuable by its absolute freedom from iron, especially for glass making. By passing the liquor at zero, over the pipes through which the fresh liquor is brought to the machine, these are economically reduced to about 14° F. before entering the cooler.

The sulphate is rendered anhydrous by stove heat. The liquid from the coolers is saturated with common salt from the tables, heated to boiling, and skimmed; a very fine salt (sel fin-fin) is obtained during its further concentration.

When it marks, while boiling, 34° B. (1·288), it is allowed to cool in crystallizers, where it deposits the salt (KCl, 2Mg Cl, 12 HO) free from common salt, and containing all the potash present. This is treated with half its weight of cold water; after an hour's stirring it is allowed to settle; the solution containing the magnesium salt and a little of the potash, is returned into the cycle of operations. The chloride of potassium, after draining, contains about 90 per cent. of pure chloride.

If the deeply coloured mothers from this last crystallization, are concentrated to 38° B. (1·33) and cooled, they deposit considerable quantities of white crystalline chloride of magnesium, accompanied by traces of a bromide.*

Lastly, the mothers from this crystallization, contain the greater part of the bromine, which is obtained in the usual way by distillation with oxide of manganese and sulphuric acid.

The advantages of the artificial cooling are—

* M. Balard suggests several applications for this salt; among others, that of a source for hydrochloric acid, when the decomposing furnace shall have been superseded by the production of sulphate on his plan.

1. The loss by absorption is much less, falling on liquors at 28° B., instead of 35°.

2. The process is more manageable, the products more sharply defined, and the results more quickly obtained.

No. VIII.—SOLUBLE PERUVIAN GUANO.

A process for increasing the fertilizing action of this remarkable substance, was patented about four years ago, by Dr. Richardson, the beneficial results of which have since been confirmed, by the researches of Liebig, in Germany, and more recently by Dr. Vœlcker, in this country.

This Soluble Peruvian Guano can be sold at £11 per ton, and yet its intrinsic value is greater than that of the original Guano, as the following analyses and valuations prove :—

Analysis of Peruvian Guano.

				Value of 100 tons.	
Moisture...	15·10			£	
Organic Matter...	51·27	×	£1	51·27	
Phosphate of Lime	22·13	×	£7	154·91	
Phosphoric Acid	3·23				
Equal to Phosphate of Lime made soluble ... 7·00		×	£33	231·00	
Alkaline Salts, &c.	6·07	×	£1	6·07	
Insoluble Matter	2·20				
	100·00				
Ammonia	16·42	×	£56	919·52	
					£1362·77

Or £13 12s. 5d. per Ton.

Analysis of Soluble Peruvian Guano.

				Value of 100 tons.	
Moisture...	18·00			£	
Organic Matter...	50·54	×	£1	50·54	
Soluble Phosphate of Lime ...	12·32				
Equal to Neutral Phosphate made Soluble ... 19·22		×	£33	634·26	
Insoluble Phosphate of Lime...	2·36	×	£7	16·52	
Alkaline Salts, &c.	2·69	×	£1	2·69	
Hydrated Sulphate of Lime ...	12·44	×	£1	12·44	
Insoluble Matter	1·65				
	100·00				
Ammonia (fixed)	12·65	×	£56	708·40	
					£1424·85

Or £14 4s. 10d. per Ton.

The soluble Peruvian Guano is not liable to deteriorate in quality like the original guano, as all the ammonia is fixed, and the phospates are rendered soluble.

It is gradually coming into more general consumption ; and the following field experiments prove its value as a fertilizer, for both white and green crops :—

FIELD EXPERIMENTS, WITH SOLUBLE PERUVIAN GUANO.—WHITE AND GREEN CROPS.

Nature of Soil.	Extent of Ground experimented on.	Preceding Crop.	Previous Manure.	Present Crop.	When Sown.	Weight of Manure used.	Nature of Manure.	How applied.	PRODUCE. If Root Crop. Weight of Roots.	If Root Crop. Weight of Tops.	If Cereal. Average Weight.	If Cereal. Weight of Straw.	REMARKS.
Made by Mr. JOHN HOOKER, on a Farm known as Hammonds, situated in the Parish of West Horsley, in the County of Surrey, 1860.													
						c. q. lb.			T. c. lb.	T. c. lb.			
Loam, with many broken flints	1 Acre	Wheat	Hay	Green Round Turnips	July 20	3 0 0	Peruvian Guano	½ sown, ½ drilled with the seed	10 9 20	2 12 4	Weighed January 28, 1861.		Did not come up so well as the rest. The Manure was too strong for the young plant.
	1 Acre	„	„	„	„ 20	3 0 0	Soluble Peruvian Guano No. 1		12 18 60	2 9 12			
Tertiary on the North Side of the North Downs	1 Acre	„	„	„	„ 20	3 0 0	No. 2		12 2 0	2 19 75			12 bushels per acre of Turf Ashes drilled with the seed.
	1 Acre	„	„	„	„ 20	3 0 0	Superphosphate		8 2 54	1 10 0			
	1 Acre	„	„	„	„ 20	....	No Manure	....	7 8 0	2 1 66			Width of drills 21 inches; do. of Turnips in the drills 12 inches.
Made by Mr. H. PENFOLD, on a Farm known as Lynd, situated at Chertsey, in the County of Surrey.													
Light	1 Acre	....	....	Skirving Swedes	July 25	1 0 0	Peruvian Guano	Broad cast	16 10 0				
Do.	Do.	....	....	„	„	1 0 0	Soluble Peruvian Guano	„	21 0 0				These grew the best all through the season.
Made by Mr. NASH, on a Farm known as Wood Cote Hill, situated in the Parish of West Horsley, in the County of Surrey, 1860.													
Clay, containing flints, Tertiary on top of the North Downs	1 Acre	Wheat	Clover Hay	Green Round Turnips	July 19	3 0 0	Peruvian Guano	½ sown, ½ drilled with the seed	6 12 101	2 9 20	The Turnips were weighed January 28, 1861.		This was hoed 8 or 9 days before No. 2, and it is rather better land.
	1 Acre	„	Fed off by Sheep		„	3 0 0	Soluble Peruvian Guano		7 7 26	2 13 64			The rows are 2 feet apart and the Turnips 12 inches in the row. There was also 10 bushels of Turf Ashes drilled with the seed per acre in each case.
	Calculated to 1 Acre		1 Cut made into Hay.	„	„		No Manure	No Manure	1 3 4	0 17 76			
	1 Acre	„	Do.	„	„	2 0 0	Superphosphate, bought at Guildford Market	....	3 17 16	1 0 0			
Made by Mr. D. HOOKER, on a Farm known as Wix Farm, situated in the Parish of West Horsley, in the County of Surrey, 1860.													
Upper Chalk, mixed with Clay, on the top of the North Downs, North aspect	⅜ of an Acre	Beans	Peruvian Guano	Green Round Turnips	July 19	2 0 22	Peruvian Guano	½ sown, ½ drilled with the seed	7 10 0	2 5 80	Weighed January 28, 1861.		The Turnips came up quicker and better than No. 1.
	Do.	„	„	„	„	2 0 0	Soluble Peruvian Guano		9 5 84	2 2 96			5 bushels of Turf Ashes drilled with the Manure on each piece. Width of drills 21 inches; do of Turnips in the drills or row 12 inches.
	Do.	„	„	„	„	No Manure	No Manure	....	2 11 48	1 0 0			
Made by Mr. JOHN HOOKER, on a Farm known as Dairy Farm, situated at Walton-on-Thames, in the County of Surrey.													
											c. q. lb.	T. c q. lb.	
Loam	1 Acre	Mangold Wurzel	Farm Yard Dung	Wheat	Novembr.	1 0 0	Peruvian Guano	Broad cast	....	....	14 2 1	1 14 1 4	
Do.	Do.	„	„	„	„	1 0 0	Soluble Peruvian Guano	„	....	....	16 2 14	1 14 2 5	This grew the best all through the Season. The Manure was sown broad cast, and hoed in on the 10th of July, 1861.

*** The same weight of Manure to be applied in each case, and the same method of application employed, but the particular method is left to the judgment of the Experimenter.

No. IX.—JET.

This material takes its name from a river in Lycia, which was called Gages in the time of Pliny, and the small pieces of jet obtained in the locality were called *gagates*, afterwards corrupted into *gagat*, and ultimately into *jet*.

It is also called *black amber* in Russia, because it is electrical when rubbed, and being often found in sand and gravel beds.

This substance was probably worked by the Danes in this country, as the Romans are known to have made use of it for ornamental purposes. Charlton states that he found, in one of the Roman tumuli, near Whitby, the ear-ring of a lady, in the form of a heart, lying close to the jaw-bone. During the period when the Abbey of Whitby was frequented by pilgrims, jet rosaries and crosses were common. The manufacture was continued until the time of Elizabeth, when it ceased, and was not resumed until about the year 1800, since which period the manufacture has become of great importance to the district.

It is found in small patches in the top and bottom portions of the upper lias. The area in which it has been found is, however, limited, being confined to the alum shale rock.

It is first found, south of Whitby, on the estate of Mr. Hammond, near to Peak Hall, and, going northwards, it is met with in the Mulgrave mines, then in the mines of Lord Dundas, terminating at Skinningrove Beck. The jet district then retreats inland to the west, touching Eston, backwards to the Guisbro' mines, and is found in the mines worked at Roseberry, Carlton, all along the Cleveland banks to Aincliffe, and thence as far as Easingwold Beck. It is also found in all the valleys of the Esk, in Rosedale, Fawdale, Bransdale, Bilsdale, and the whole of the surrounding hills.

The jet rock varies from six to seven yards in thickness, but the jet is found in very small quantities, varying from an ounce to 2 cwts., and generally accompanied with fragments of bituminised wood of coniferous trees.

Small pieces of jet are sometimes found washed up on the beach.

A common quality is also found in the sandstone near Whitby, called *soft jet*, of which articles of an inferior description are made. Jet has also been found in small pieces in the Kimmeridge clay in Dorsetshire.

It is obtained by excavating it from the face of the cliffs on the sea coast, by the sides of the valleys, or from old quarry workings in the interior of the county. Although the best portions sometimes realize from 12s. to 14s. per lb., every attempt to mine it systematically has proved unfortunate.

A peculiar odour is sometimes evolved from the rock in which the jet is found; and Simpson states that it, or a similar material, is often found in a liquid or soft state in the chambers of ammonites, &c.

A fine specimen from Whitby, analysed by Dr. Richardson, was found to contain as follows :

Carbon	79·77
Hydrogen	4·30
Nitrogen	0·47
Oxygen	13·22
Sulphur	0·91
Ashes	1·33
	100·00

It is manufactured into every kind of ornament; and this business is the most important trade in Whitby.

The number of men and boys employed in searching for jet is about 250, while between 600 and 700 men and boys are engaged in its manufacture at Whitby and Scarbro'.

The total annual wholesale value of the articles made in the above localities, amounts to £125,000.

We have to express our thanks to Mr. Harrowing, of Whitby, for much of the information relating to this interesting mineral.

No. X.—BARYTA MINERALS.

Little or no sulphate of baryta is either raised or manufactured in this district, the consumption being supplied from Hull, Glasgow, and other places.

The carbonate of baryta, on the other hand, is almost exclusively obtained from mines in this locality, the quantity produced being about 1,500 tons per annum.

Although it cannot be called a chemical manufacture, yet, inasmuch as it is afterwards submitted to chemical treatment, it merits a passing notice.

It is largely exported to France and Germany, where it is dissolved in hydrochloric acid. The baryta is afterwards precipitated as sulphate, which is washed and dried. It is used as a white color, and for coating visiting cards, &c., being sold under various names, Satin white, Blanc fixe, &c.

It was at one time converted into nitrate of baryta, which was decomposed by heat to obtain baryta, which was employed in Dubrunfaut's process for separating sugar from beet-root molasses.

There are various qualities, of which the following analyses represent the per centage of carbonate of baryta present in some of the kinds.

Superior Lump	... ...	„	
No. 1 do.	... ...	94·15	per cent.
„ 2 do.	... ...	92·95	„
3 do.	... ...	„	
Superior Small	... ...	97·15	„
No. 1 do.	... ...	94·36	„

ON THE

VITREOUS AND CERAMIC MANUFACTURES

OF THE DISTRICT.

GLASS	...	R. W. SWINBURNE.
EARTHENWARE	...	T. C. MALING.
FIRE-CLAY WARES	...	J. COWEN.

THE MANUFACTURE OF GLASS.

BY
ROBERT WALTER SWINBURNE.

THE Committee of Local Industry have desired me to prepare a paper on the Glass Manufacture of this district; and I am requested to advert to its early local history, its past and present condition, the improvement in its processes, and its present extent of produce. These instructions, of course, preclude any exposition of glass making as an art, and, therefore, in the following remarks the subject will be treated as regards its economic position in this locality, and not in relation to its chemical or mechanical processes.

In preparing the following statement I have been much assisted by Messrs. James Hartley and Co., of Sunderland, Messrs. Sowerby and Neville, of Gateshead, Mr. Bowron, of Stockton, and Mr. Wailes, of Newcastle.

Newcastle-on-Tyne, and the district immediately adjacent, has long been celebrated for the manufacture of glass; and that kind used for architectural purposes, which may be considered the most important branch of the art, was first made in Great Britain within the precincts of this ancient borough.

The manufacture, as carried on so long in this locality, consists of the following principal departments, viz., Plate, Crown, Sheet, Flint, and Bottle Glass.

PLATE GLASS.

The art of casting plate glass by throwing the molten material on an iron or copper table, and rolling it into a sheet of equal thickness, was first adopted in England, in Lancashire, in 1771; but there is abundant proof that plate glass, of smaller dimensions, was made before that time at South Shields, near this town, where is situated the only

manufactory of plate glass in this district. In the early part of the seventeenth century, an article called blown plate glass was made at that place, and the manufacture was continued by the family who originally established it, until 1845, when the process was abandoned, being entirely superseded by the cast plate. In this is afforded an instance of the superiority of machinery over manual labour. Blown plate glass, which was the great original of the art in all countries, depended entirely in its manipulation on the strength of lung and dexterity of muscle of the individual operator, whose *chef d'œuvre* was about 4 feet long and 2½ feet wide; whereas the cast plate is made by the co-operative effort of 20 men, who move from the furnace the crucible in which the material is melted, and by means of powerful machinery roll it into a plane of any required dimensions. The record of the daily manufacture of blown plate glass at South Shields, in 1750, is still extant, and affords a curious proof of the infancy of the art and of the difficulties of the operator. Up to the year 1845, the returns of the Excise duty show that there was more plate glass made at South Shields than at any other manufactory in the kingdom. In that year the Excise duty on glass was abrogated, and, in consequence, the produce of this manufactory has been quadrupled. Previous to 1845, the quantity of unpolished plate glass blown and cast at South Shields was 312,000 feet per annum. Now, its capability of produce is 1,248,300 feet per annum.

A new kind of plate glass, called rolled plate, has been for some time manufactured at Sunderland, by the spirited firm of Messrs. James Hartley and Co. The invention is due to Mr. James Hartley, who has had the honour of establishing a new branch of manufacture of great public utility. This new article somewhat resembles unpolished plate glass, but is lighter in substance, and eminently fitted for roofing and other purposes of construction where translucency only is required. It is made in two or three other places in the kingdom, but Messrs. Hartley and Co. alone produce 18,000 superficial feet per week, or nearly 1,000,000 feet per annum, representing a value of nearly £15,000.

CROWN GLASS.

Ordinary window glass was first used in Great Britain for architectural purposes at the great monasteries at Monkwearmouth, on the river Wear, and at Jarrow on the Tyne.

The Venerable Bede, our first ecclesiastical historian, who flourished at the former place in the seventh century, relates that his cotemporary,

the Abbot Benedict, sent for artists beyond seas to glaze the monastery of Wearmouth. St. Bede and St. Benedict were, in their day, great promoters of literature and the fine arts, and they imported from all parts of Europe everything that could give splendour to their churches and inspire their disciples with a lofty enthusiasm. Such was the change made in their churches by the use of glass instead of other and more obscure substances for windows, that the unlettered people avowed a belief, which was handed down as a tradition for many generations, that "it was never dark in old Jarrow Church."

By a singular coincidence, the first manufactory of window, or crown glass, in Great Britain was established at Newcastle-upon-Tyne, within a few miles of these monastic establishments. In the year 1616, Admiral Sir Robert Mannsell erected glass works at Newcastle, which were carried on, without interruption, till nearly the middle of the present century, when they were closed.

When the British Association last held their meeting in Newcastle-upon-Tyne, there were six large crown glass manufactories in operation on the river Tyne, producing annually upwards of 7,000,000 feet of window glass.

These manufactories have now ceased to exist, owing chiefly to the introduction of sheet glass into this country, and the comparatively low price at which plate glass can be now had. Crown glass is made in a circular shape, which, of course, involves a considerable loss of surface in being reduced to the rectangular shape, in which all window glass is used, and the knob, or "bullion" in the centre, limits the size of the window panes. The public taste now demands panes of large dimensions, an object which is attained by the use of sheet glass, and although crown glass maintains the palm of greater brilliancy, yet it must be esteemed in the light of an effete manufacture, and will gradually die out in this country as it has already done on the continent. The manufacture of sheet has been at different times carried on to a small extent in the old window glass works of the river Tyne, but it is now entirely abandoned, so that, in the birthplace of the art in England, there is now not a foot of window glass manufactured. But, in the progress of the arts, we constantly see that one process is superseded by another; and although this important branch of industry has become extinguished on the Tyne, a cognate process has been established with great success in the neighbouring district of the river Wear, producing a larger quantity of window glass than was made in the six extinct crown works of the Tyne. To

Mr. Chance, of Birmingham, and Mr. Hartley, of Sunderland, we are indebted for the introduction into this country of the manufacture of

SHEET GLASS,

Which may be said to have given a new feature to our public and private edifices. Made originally in a rectangular shape, it is more mechanically adapted for use than crown glass, and having no knob, or "bullion," in the centre, it supplies the desideratum of large panes at a low price. So great were the difficulties attending the introduction of this manufacture, that although the original experiments commenced in 1832, the manufacture was not fairly established until 1838.

There are two manufactories of sheet in this district, and their united produce is 8,000,000 superficial feet per annum, which, at a low rate of value, is worth £50,000.

Messrs. James Hartley and Co., of Sunderland, state that their make is equivalent to one-third of the English-made sheet glass *consumed* in England, and equal to about one-fourth of the entire produce of this country.

This article has long been manufactured on the continent, but owing to the vexatious restrictions of our Excise Laws, it could not be made here, and the gentlemen who introduced it into England were obliged to obtain an alteration of the laws in order to construct the proper furnaces for its manufacture.

FLINT GLASS (THE CRYSTAL OF THE ANCIENTS)

Has been made in Newcastle and its neighbourhood for a very considerable period; but its early history in this locality is obscure. It is more than probable that its manufacture was first introduced here by Sir Robert Mannsell, who, as before remarked, established glass works in this borough in 1616. This gentleman being a manufacturer of flint glass in London, it is very probable that some of the early flint glass works in this neighbourhood owe their origin to him. In the Council books of this town mention is made of flint glass works existing in 1710 and 1737. Originally made from triturated flint, that designation has been continued, although the flint of former days has long been superseded by silicious sand. The manufacture is divided into two branches, viz., blown and pressed; the first being produced exclusively by manual labour, and the latter chiefly by machinery. The blown glass retains its eminence for brilliancy, in consequence of its facets being produced by elaborate polishing, whereas in pressed glass, they are the result of pres-

sure of a metallic mould on the plastic surface in a heated state. Owing to causes hereafter adverted to, the manufacture of blown flint glass has, in this neighbourhood, declined as much as fifty per cent.; but the manufacture of pressed glass has recently been prosecuted with great vigour and success in this locality. One firm, which is at the head of this branch of trade, formerly produced annually 350,000 lbs. weight of blown flint glass, now make of pressed glass about 3,000,500 lbs. weight. The annual produce of flint glass on the Tyne and Wear is estimated, by competent authority, at 10,000,000 lbs. weight, the wholesale value of which—including its cutting and ornamentation—is about £200,000.

The manufacture of pressed glass has cheapened flint glass articles to such an extent, that almost the poorest of the population may be supplied with elegant articles of domestic use, which a few years ago were far beyond their reach.

GLASS BOTTLES.

As in other branches of the glass manufacture, this district has been most eminent for the production of common glass bottles. In the Common Council books of this borough, of the date of 1737, four bottle manufactories are specifically mentioned; and there is proof that the Close Gate Bottle Houses in this town were of still greater antiquity.

This neighbourhood was deemed especially adapted for the manufacture of bottles, not only from the cheapness of fuel, but from the vicinity of an extensive fluvial deposit at Jarrow Slake, which was long used as a material in the manufacture. It consisted chiefly of silicious, calcareous and argillaceous earths in excessive comminution, mixed with carbonaceous and saline matter—which last was held to be a powerful solvent of the earthy matter of which the bottles are made.

Experience has long substituted more simple materials for this primitive compound; and it is found that bottles can be made wherever lime and sand are found, independently of this once highly-esteemed "deposit of nature." Since the repeal of the duty, in 1845, the produce of common glass bottles has increased four-fold; but there are other causes that have materially contributed to this result. The rapid rise of Australia, and the increasing taste for bitter beer there, in India, and in most parts of the world, have created an immense demand for bottles.

During the year 1862 there were 47 bottle houses in operation on the banks of the Tyne, the Wear, and the Tees, and their produce was about 4,230,000 dozens.

There has been no important improvement in the manufacture of black bottles for the last 20 years, and in the manipulation there has been no change. The baneful union amongst the workmen forbids all attempts in that direction. The ancient process of fritting, at one time in use in the manufacture of window glass, continues to be used by the maker of black bottles; and no process has been adopted by which, as in other branches of the art, the component materials can be thrown at once into the crucible without heating in a preparatory furnace.

A new manufacture of bottles has recently sprung into existence, and this district has taken a prominent part in it. A mixture, somewhat similar to that used in making crown and sheet glass, is employed in making what are termed pale bottles, the colour of which is that of window glass; besides being of a light colour, the skill of the manufacturer has given them every variety of tint by the interfusion of metallic colouring matter; and vessels of various, and in many cases of tasteful design and colour, are made in great abundance, and are in most extensive use. A firm at Blaydon, in this neighbourhood, has attained considerable eminence in this new branch of business, and there is no doubt, that it furnishes a field of great improvement in the approximation of its products to the lucidity of flint glass, without the use of the expensive metallic ingredients used in that manufacture.

STAINED GLASS.

The beautiful art of coloured glass, or what is termed stained glass, has been carried on most successfully for some years in this borough by Mr. William Wailes and others, and the tasteful designs and beautiful colouring of Mr. Wailes' numerous works have given him a great celebrity throughout the kingdom. A great improvement has been made in this description of glass, inasmuch, as exterior staining has been superseded by glass made of the required tint in the crucible of the manufacturer. The glass therefore is not stained, but is inherently of its peculiar colour.

It is manufactured of any tint at the works of Messrs. James Hartley and Co., of Sunderland. This process of making coloured glass in the crucible has restored the art to its pristine state, for in such manner glass was made by the old masters. By its means the brilliancy and durability of the old coloured glass has been obtained, and all the colours of antiquity are produced by our modern manufacturers in greater brilliancy—ruby alone excepted.

In the production of this colour our manufacturers are gradually approaching the ancient standard. It is ascertained that there is something in the undulating and imperfect surface of the glass of the fourteenth century, which renders it more adapted to display intensity of colour than the more perfect glass of modern times. Hence, the coloured glass makers resort to the use of a glass as the basis of their colour, which of itself is of the most rude and imperfect character.

IMPEDIMENTS TO PROGRESS.

A great impediment to the progress of the glass manufacture in this district, is the trades' union amongst the workmen. In the blown flint trade, the union exercises a power which amounts to a domination over the employer. In one case, at least, a manufacturer permanently gave up his business from this cause, and in other cases large works have been for a time wholly suspended. At present the blown flint glass maker can only obtain a workman by taking the first on the union list, and he must take the chance of his having the requisite qualifications, and must receive him without a character. The workmen in a large window glass factory on this river struck work, because a non-union man had been employed in a subsidiary part of the process. They abandoned their work the moment the obnoxious man made his appearance: the materials on which they were operating, of the value of £300, were spoiled, and the works were a long time dormant. The relation of master and man in the blown flint and bottle trades amount to a chronic strike. Labour in these trades is the great element of expense,—the men regulate that expense by a dictation against which the master is helpless.

A respectable flint glass manufacturer makes the following statement:—

The glassmakers' society decides upon the number of apprentices the master shall employ, and the rate of wages he must pay his men. It also orders the allowance of what is termed "drink money," which is daily spent in the purchase of intoxicating liquors. This induces unsteadiness in the men, and in the majority results in habitual inebriety. The apprentices and boys are encouraged by precept and example to follow in the same course, so that the evil is perpetuated. The master is powerless to prevent intoxication, for if the drink money is withheld the whole of the men strike work. The manufacturer is obliged to provide the men a certain quantity of what is termed "metal," *i.e.*, molten materials to make into goods, but if they cannot, or will not, work up

all this metal, the master has no redress; it must be laded out of the crucibles as waste, and the employer must give the men more drink for lading it. Thus, these infatuated men—many of them endowed with great ability in their craft—impair their own efficiency by their sensuality, violate the first principles of political economy, and inflict upon the employer a burden which hopelessly fetters him in the race of competition and improvement.

This insensate oppression is derogatory to the intelligence of our time, and most seriously obstructive to our local commerce. Large orders have been transferred from the Tyne to Belgium, and the manufacturers here purchase foreign glass, for the production of which they have every appliance at home, except labour at a reasonable cost. The success of the pressed glass manufacture is greatly to be attributed to its being independent of skilled workmen, its operations being chiefly carried on by machinery.

Another impediment arises from the prohibitory duties imposed by foreign Governments.

The English makers of plate and window glass have represented to our Government that their cost of labour is 60 per cent. more than that of the foreign rivals who are allowed to import their produce to this country duty free, whereas the continental duties are prohibitory. In many articles the English manufacturer could compete with his foreign rival. He asks no protection, but desires equal terms with others, and he will take his chance in the competition. The English manufacturers of glass universally complain that our diplomatists negotiate treaties, and settle tariffs without pre-consultation with persons versant with the trade; and they think that better terms might have been had if more information had been previously obtained.

IMPROVEMENTS.

As regards glass processes generally, it cannot be denied that they present a great field for improvement. To those who study them in their scientific bearings, there appear many desiderata; and it is to be hoped that the manufacturers engaged in this important branch of our national commerce, will energetically pursue the improvement of an art which most materially promotes the physical comfort and intellectual taste of the people—which has brought the costly crystal of antiquity to the tables of the poor, and has given, without stint, the light of heaven to the humblest of their habitations.

ON

THE MANUFACTURE OF EARTHENWARE.

BY

CHRISTOPHER THOMPSON MALING.

THE manufacture of white earthenware was introduced into this district by Mr. Warburton, at Carr's Hill Pottery, near Gateshead, about 1730 or 1740. These works were very successfully carried on for 70 years, when they gradually declined, and in 1817 were closed. A small portion of the building is still used as a brown ware pottery.

The next manufactory was built by Mr. Byers, at Newbottle, in the county of Durham, about 1755, where brown and white earthenware still continue to be made.

In 1762, Messrs. Christopher Thompson and John Maling erected works at North Hylton, in the county of Durham; their successor, Mr. Robert Maling, in 1817, transferred his operations to the Tyne, where his descendants still continue the manufacture.

St. Anthony's, Stepney Bank, and Ouseburn Old Potteries were commenced about the year 1780 or 1790.

Messrs. A. Scott and Co., and Messrs. Samuel Moore and Co., erected potteries at Southwick, near Sunderland, the former in the year 1789, the latter in 1803.

The pottery carried on by Messrs. John Dawson and Co., at Hylton, was built by them in 1800.

The works of Messrs. John Carr and Sons, at North Shields, were erected in 1814.

Messrs. Thomas Fell and Co. built St. Peter's Pottery in 1817.

The establishment of Messrs. Skinner and Co., Stockton-on-Tees, dates from 1824.

There are now about 25 potteries in this district, of which, on the Tyne, 6 manufacture white and printed ware, 4 white, printed and brown ware, and 3 brown ware only; employing 1200 people, and manufacturing

yearly about 12,000 tons of white clay and 3000 tons of brown clay, and consuming in the process of manufacture about 34,000 tons of coal.

On the Wear there are 2 potteries manufacturing white and printed ware, 2 white, printed, and brown ware, and 2 brown ware only; employing about 500 people; manufacturing yearly about 4000 tons of white clay, 1500 tons of brown clay; consuming in the manufacture about 14,000 tons of coal.

On the Tees there are four potteries manufacturing white and printed ware, employing 500 people, manufacturing 5000 tons of white clay, and consuming 13,000 tons of coal. And 2 at Norton manufacturing brown ware; the particulars of their operations I have not been able to obtain.

The potteries in this district, being situated upon navigable rivers, have great advantages over their inland competitors, Staffordshire and Yorkshire. The expenses on clay from sea freight, and inland carriage, average 13s. per ton to Staffordshire, and 5s. per ton to this district; and in flints the advantage is still greater, in Staffordshire the average being 19s. per ton against 4s. 6d. per ton here. Coals, although a little dearer here per ton, are so much superior in quality that 80 tons of Newcastle coals are equal to 100 tons of Yorkshire or Staffordshire.

About 1858, Messrs. Skinner and Co., of Stockton-on-Tees, first applied Needham and Kite's Patent Filtering Press for expelling the surplus water from the slip, which had formerly been done by evaporation. This is a much cleaner and better process than the old system, and is now adopted by 30 or 40 potteries in England and Scotland.

With the exception of 3 potteries in this district, and 1 at Glasgow, machinery has been very little applied to the manufacture of earthenware, and even at these works not nearly to the extent to which it is capable of being profitably adopted.

One manufactory on the Tyne (Ford Pottery) having the best machinery, supplies at least 80 per cent. of the jars used by confectioners for marmalade and jam, &c., in England and Scotland.

The description of goods manufactured in this district, is that used by the middle and working classes, no first-class goods being made here. The principal markets, in addition to the local trade, are the Danish, Norwegian, German, Mediterranean, and London, and for exportation to the colonies. The trade to the United States being so very small from here, the American war has affected this district less than any other.

ON

THE MANUFACTURE OF FIRE-CLAY GOODS.

BY

JOSEPH COWEN, BLAYDON BURN.

FIRE-CLAY is obtained in large quantities in the two counties of Durham and Northumberland.

It usually lies beneath the Coal-measures in layers, varying in thickness from 12 inches to 5 or 6 feet. It is found in most abundance, and in best quality, beneath the coal used for coking and manufacturing purposes. Silica and alumina are the two substances of which fire-clay is chiefly composed. The refractory character of any sample of fire-clay is determined by the proportions in which these two ingredients are contained, and by the absence of lime, iron, and other easily fluxible substances.

The best descriptions of fire-clay—those which, when manufactured, are capable of resisting the greatest heat—always contain a large portion of silica. The following are a series of analyses of samples of fire-clay taken from seven seams, all worked in the mines belonging to one fire-brick manufacturer, situated a few miles west of Newcastle:—

Nos.	1	2	3	4	5	6	7
Silica	51·10	47·55	48·55	51·11	71·28	83·29	69·25
Alumina ...	31·35	29·50	30·25	30·40	17·75	8·10	17·90
Oxide of iron ...	4·63	9·13	4·06	4·91	2·43	1·88	2·97
Lime	1·46	1·34	1·66	1·76			1·30
Magnesia ...	1·54	0·71	1·91	trace	2·30	2·99	
Water and organic matter ...	10·47	12·01	10·67	12·29	6·94	3·64	7·58

From these analyses it will be seen that clays of various kinds and qualities lie in close contiguity to each other, and can be worked out of the same mine.

The possession of such a series of beds of clay so situated, gives great facility to the manufacturers in this district, as it enables them to mix the different descriptions of clay with a view of adapting the articles made therefrom to different purposes. This is a facility enjoyed by the northern fire-clay manufacturers to a greater extent than by those in any other part of the United Kingdom. Fire-clay being found in more abundance, and being capable of being more economically worked in the Northern Coal-field than in any part of Europe, accounts for the extent of the business in fire-clay goods in this district.

The trade in fire-clay goods is of comparatively recent origin. Its progress at first was slow, but during the last 40 years it has extended rapidly, and is still on the increase. The extension during the last 25 years has been especially marked and important. Fire-bricks were first made on the Tyne about 100 years ago.

For many years all that were made were consumed in the manufactories in the neighbourhood.

Slowly but gradually the trade increased, and the goods made were sent in larger or smaller quantities to different parts of the United Kingdom, and to some of the chief ports in Europe and the British Colonies.

The extent of the trade in the year 1838 was as follows:—

The number of bricks manufactured at that time, per annum was about	7,000,000
The local consumption then was about	2,500,000
The quantity sent to other parts of the United Kingdom was about	3,000,000
And the quantity exported was about	1,500,000

The extent of the trade at the present time is as follows:—

Number of fire-bricks made per annum, about	80,000,000
The local consumption is estimated at	43,000,000
The quantity sent to other parts of the United Kingdom is estimated at	27,500,000
And the quantity exported	9,500,000

It will be seen from the above figures that the local consumption of fire-clay goods has increased, during the last quarter of a century, 1700 per cent., the home trade upwards of 900 per cent., and the export trade upwards of 600 per cent. The average increase has been about 1100 per cent.

There has been very little alteration in the art of making fire-bricks, except in the construction of the moulds, which were at first made of

wood, and are now made of brass or other metal, and some of glass. The way in which bricks are made at present does not differ materially from the way they were made a century ago. Repeated attempts have been made to apply machinery to their production, but heretofore without success. The plastic nature of fire-clay, and the character and variety of the articles made from it, renders the application of machine power difficult, and the advantages derivable from its adoption comparatively trifling. In Wales machinery has been used for making fire-bricks, but the fire-clay of that district differs in its nature from that got in the North of England.

Machinery has, however, been very extensively and successfully applied to the preparation of the raw material. Indeed, had it not been for the improved mode of grinding and pugging the clay—which machinery has supplied—it is doubtful whether the trade could have developed in the way it has done. Great improvements have also been made in the manner in which various kinds of clay are mixed and prepared for manufacturing purposes.

The exposure of fire-clay to the action of the weather has a most important and beneficial influence on its quality, as it separates the impure portions from the good clay, and enables them to be seen and picked out with ease.

Those manufacturers who have capital and sufficient space to weather their clay effectively, and who are so favourably situated as to have at their command a variety of clays, containing the essential ingredients in different proportions, have great facilities for preparing the materials, and adapting them to make articles suitable for all purposes for which fire goods are used.

Forty years ago, the manufacture of fire goods was limited to making fire-bricks of the ordinary shapes and sizes. Since that time fire-clay goods have become much more generally used, and the articles made from fire-clay are both numerous and complicated. Articles intended for ornament, as well as goods designed for the most substantial works, have been alike constructed from it with success, and hence, also, its use as an article of commerce is daily increasing. Gas retorts made of fire-clay have, within the last 20 years, gradually become adopted, and they are now generally in use in all gas works.

The improvement in the manufacture of this class of fire goods has been very considerable. Great difficulties were experienced at first in making retorts of fire-clay of the required dimensions and free from

cracks; but as the trade extended these difficulties decreased, and the demand for the article increased.

The number of clay retorts now made in this district will be about 12,000 per annum.

The use of clay retorts by gas companies has destroyed the consumption of iron retorts, and caused a very considerable saving in the manufacture of gas. All large gas establishments have been enabled, by the use of clay retorts instead of iron ones, to considerably increase their profits. Some are understood to have been able almost to double their dividends through the change from iron to clay retorts. The use of clay retorts has, however, diminished the number of fire-bricks, tiles, and the various smaller kinds of fire goods formerly consumed by the different gas companies in setting their iron retorts.

Fire-clay pipes are now often used for lining chimneys in dwelling houses, hospitals, &c. The use of such pipes, as safeguards against fire, cannot be too highly recommended. Fire-clay is also largely used for making chimney tops, baths, flower vases, and other ornamental articles.

Many of the common and lowest priced description of fire-bricks are now used for ordinary building purposes in the construction of dwelling houses, warehouses, &c.

The great increase in the demand for fire-clay goods has been caused by the increase in the number of iron, gas, and alkali works, and the rapid and great extension of the trade for coke for locomotives.

The price and quality of fire goods vary considerably. Fire-bricks made of the inferior descriptions of clays and manufactured in the least expensive way, are sold as low as 30s. per 1000, while the best kinds, made from superior clays and manufactured with the greatest care, are sold at 55s. per 1000.

Fire-clay has, for some years past, also been used extensively in the manufacture of sanitary pipes, for which purpose it is well adapted. The smaller main sewers and branch drains in all new works are now made of glazed fire-clay or earthenware pipes. Clay pipes, although in their adaption to drainage comparatively modern in their use, are yet of great antiquity, having been found in the ruins of Nineveh in a perfect state of preservation, where they appear to have been used for the conveyance of water to the various aqueducts in the city.

Fire-clay is found to be a more suitable material for the manufacture of sanitary tubes than either earthenware or stoneware. The greater amount of heat that is required to vitrify it makes the pipes better burnt,

while the thickness they are usually made increases their strength and durability, and at the same time enables them to resist the action of the chemical agents found in suspension in the liquid sewage.

At an early period of their manufacture the old system of moulding these pipes in plaster moulds was abandoned and a more expeditious method of making them was adopted by the introduction of suitable machinery, in some cases propelled by hydraulic, but more generally by steam power.

The usual form of a steam-pipe press is a simple cylindrical box, which, being filled with properly tempered clay, has a ram or plunger working in it, which being set in motion by the direct action of steam, admitted to the steam-chest by the moving of a handle, presses the clay to the bottom of the cylinder through dies of various sizes. The socket and the pipe being made simultaneously at one blow, and the pipe being cut with a wire is carried off on boards to stiffen, after which a slight dressing by hand makes it ready for the kiln where it is burned.

The rapidity with which these pipes are made is very great, 5 men or boys being able to turn out about a mile of them in a day, from 3 to 6 inches in diameter of 2 or 3 feet lengths, or a proportionate number of the larger sizes. The highest bore these pipes have reached is 3 feet diameter, but these are very seldom used, being found more expensive than a brick drain of the same dimensions, but 18 inches diameter pipes and under are the sizes used most generally for main and side drains.

In addition to their cheapness these pipes are found of almost universal adaptation from their internal smoothness and cylindrical form.

When properly laid and well jointed, a fall of an inch in 1000 yards will enable the sewage to flow through them without stagnation or interruption.

These pipes are all glazed externally and internally with a powerful salt glaze.

By the use of glazed fire-clay and earthenware sanitary pipes the drainage of a large number of places in the United Kingdom has been much improved.

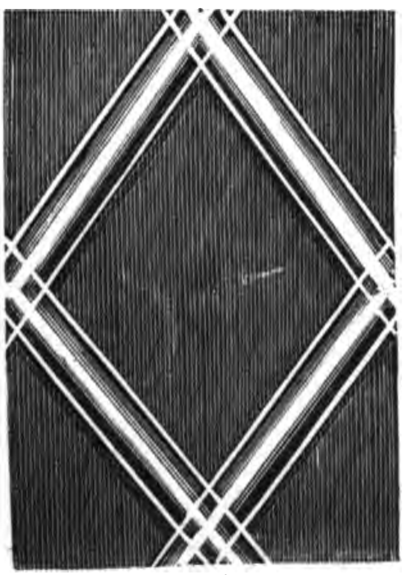
In the counties of Durham and Northumberland, Darlington, Durham, Sunderland, North and South Shields, Morpeth, Alnwick, and other smaller places have all been drained chiefly by the use of fire-clay pipes, manufactured principally on the Tyne.

Although the larger portion of these pipes are used for the conveyance of subsoil drainage, they are also used in large quantities for the

conveyance of water. They have been approved of by many hydraulic engineers for that purpose as the proper description of pipe to be used where the pressure is not great, as, by their use, the evil accruing to the quality of the water by transmission through lead or metal pipes is entirely avoided. The pressure these pipes will sustain is very considerable. Some manufactured on the Tyne have been tested, and found to sustain a pressure of 80 lbs. to 120 lbs. on the square inch. This is a very fair pressure for a pipe manufactured of clay, but as the manufacture progresses it will no doubt go much beyond this. Glazed fire-clay pipes form a channel for the conveyance of water which never corrodes, and in its essential properties is imperishable.

Fire-bricks made per annum, are estimated at		80,000,000
Fire-clay retorts per annum, about		12,000
Fire-clay glazed pipes made per annum, 3 in. to 15 in. diameter		175 miles
Fire-clay, ground, sold per annum, estimated at		50,000 tons
Fire-clay required to make the above bricks, retorts, and pipes, estimated at		295,000 tons
Coals required in the manufacture of the above, estimated at		150,000 tons
Men and boys employed, estimated at		3,500
Amount of wages paid per annum in the northern fire-clay works estimated at		£110,000
Fire-bricks used in the locality, estimated at ...	43,000,000	
Fire-bricks sent to other parts of the United Kingdom, estimated at	27,500,000	
Fire-bricks exported	9,500,000	
		80,000,000
Fire-clay exported, estimated at	3,000 tons	
Fire-bricks made in the year 1838, estimated at		7,000,000
Fire-bricks used in the locality in 1838, estimated at	2,500,000	
Fire-bricks sent to other parts of the United Kingdom in 1838, estimated at	3,000,000	
Fire-bricks exported in 1838, estimated at	1,500,000	
		7,000,000

No. 1.



No. 4.

APPENDICES.

No. I.—GLASS.

The manufacture of rolled plate glass is worthy of a more extended notice than was admissible within the limits of the paper on glass, read at the meeting of the Association.

In the preparation of glass for polishing, no care is taken as to its surface, that being entirely removed during the subsequent process of polishing, and a new exterior produced. Nevertheless as this unpolished glass is translucent, can be produced at a cheap rate, and is of a strength to resist hail storms and other concussions which would be destructive of crown or sheet glass, it has been used largely for roofing and other common purposes, even though its surface is rough and untransparent. The necessary thickness of unpolished plate glass is from one-fourth to three-eighths of an inch, giving it a weight of from 4 lbs to 6 lbs per foot, and this precludes its use for horticultural and other structures where heavy timber framing is inadmissible.

The rolled plate, on the contrary, can be made one-eighth of an inch thick, weighing 2 lbs per foot, and while this tenuity of substance renders it compatible with wooden or iron frames of a light construction, it is found that where plates of moderate size are used it is equally capable with rough plate to withstand atmospheric influence and ordinary accidents. The inventor has succeeded in giving it a surface quite free from the nodular or corrugated appearance of rough plate, and at the same time in imprinting upon it a pattern which gives it a more translucent appearance. The molten glass of which it is formed is thrown upon a table which is engraved or indented so as to produce the pattern required, and the glass when cooled represents the counterpart of the indents. Fig. No. 1 of the subjoined sketch represents what is called "plain patent rough plate," and has upon it only the longitudinal and parallel lines impressed on the table by a planing machine. Ninety per cent. of the consumption is of this description.

If the indentations on the table are deeper, the result is a fluted or grooved appearance as presented in fig. No. 2, which represents a piece of glass having 12 flutes to the inch. Fig. 3 has 3½ flutes to the inch. In fig. 4 the pattern is made to represent the quarry glass used in churches and other public buildings, the equilateral triangle being of translucent glass instead of the opaque lead or iron in common use. Fig. 5, represents, on a reduced scale, the stained quarry glass of a

more ornamental character than others, and No. 6 shows a specimen of diamond rough plate.

This article is made by lading the molten glass, technically called "metal," from a large crucible called a "pot," in which the materials are melted, on to an iron table where it is rolled into a flat plate. It is then transferred to an annealing kiln, where it is placed on its edge, and remains until sufficiently cooled for use. This act of lading occasions a quantity of air bubbles in the "metal," which render it unfit for use as polished glass, but do not retract from its translucency. In the manufacture of plate glass for polishing, the entire contents of the "cistern" or vessel in which the materials are melted, are thrown on the casting table, and thereby the bubbles and other defects, incident to the lading process, are prevented.

The economy of the rolled glass process, consists in the use of a large crucible instead of a small one necessary in the ordinary manufacture of plate glass. Also in the plates being made so small, as to admit of their being placed in an almost perpendicular position in the annealing kiln, instead of an horizontal one, as in the old process, which necessitates a large space and costly erections.

No. II.—FIRE-CLAY WARES.

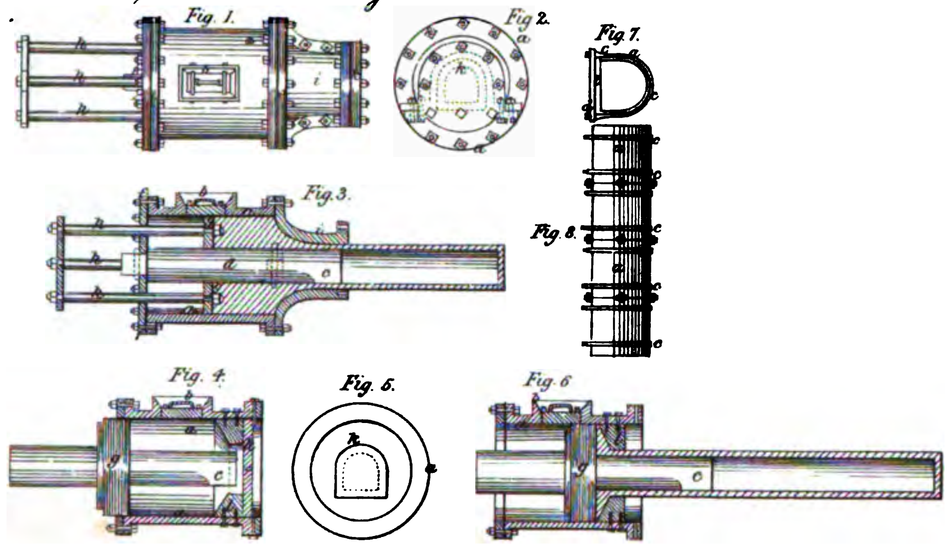
COWEN'S PATENT FOR MAKING FIRE-CLAY GAS RETORTS.

Mr. Joseph Cowen, of Blaydon Burn, the writer of the paper on "Fire-clay Wares," has a patent for making fire-clay gas retorts, a drawing and full description of which is appended.

These improvements in making retorts for generating gas may be considered under two heads. Firstly, the new combination of earthy and other materials, of which the retorts are to be constructed; and secondly, the novel kind of moulds and machinery by which the retorts are to be shaped and manufactured.

The object of the patentees is to make such clay retorts, for generating illuminating gas, as will be capable of withstanding the effects of the various changes of temperature to which they are required to be exposed, and consequently render them less liable to crack. To accomplish this, he proposes to mix with Newcastle fire-clay Stourbridge fire-clay (or any other kind of clay suitable for the purpose), sawdust, pulverised wood, charcoal, coke, carbon obtained from the interior of gas retorts, and other carbonaceous materials, in such proportions as the quality of the clay may require. The more aluminous the quality of the clay, the larger will be the quantity of carbonaceous matter required to be combined therewith. From one-twentieth to about one-fourth, by measure, of carbonaceous matter, compared to the whole mass of earthy materials employed, may be combined; this variation of quantity depending, as before stated, upon the aluminous condition of the clay—a feature well understood by potters and the makers of clay retorts. By these means the clay is rendered partially porous, and consequently less liable to crack by the change of temperature. Clay retorts, for the generation of illuminating gas, of all forms and structures, may be made of these combinations of earthy and carbonaceous materials.

Cowen's mach^y for making retorts.



A. Reid Lith Newcastle

The second part of the invention applies to the peculiar kind of moulds, and the machinery to be employed, for manufacturing gas retorts from earthy materials, which will be seen by reference to the annexed diagram.

Fig. 1 represents the external appearance, as seen from above, of the improved machine for forming retorts of clay by compression; fig. 2 is an end view of the same; and fig. 3 shows the internal parts of the machine, by means of a longitudinal section, taken vertically, *a a* is a cylindrical box or chamber, into which the plastic clay and other materials are to be introduced, through a man-hole or aperture, *b*, at the top; *c d* is a core, made towards the end *c*, to the figure of the required internal form of the retort, the other part of the core, *d*, being cylindrical and hollow, for the sake of lightness.

This core is placed concentrically within the cylindrical box or chamber *a*, and is made fast thereon by a stud and key, *e*, to the end plate, *f*, *f*, of the cylinder. A circular plate, *g*, acts as a piston with the cylinder, sliding over the core, *d*, for the purpose of compressing the plastic clay and other materials contained therein, which piston has several rods, *h*, *h*, *h*, affixed to it, whereby any actuating power or mechanical force may be applied to drive the piston forward. To the front end of the cylinder there is attached a nosepiece, *i*, *i*, with a plate, *k*, which, together, may be called the mould; for, on the piston being forced up, the plastic clay is made to fill up the nosepiece, and to mould or form the end of the intended retort, which, when the machine is in operation, will be known by small portions of the clay oozing through the hole or holes in the front plate, *k*. It will be seen by the drawing, that the retort about to be made by this machine is nearly of the transverse sectional figure of the letter D; but to this figure the inventor does not confine himself, as any other form of retort may be made, by means of the same machinery, by altering the shape of the nosepiece, *i*, *i*, and the end part of the core, *c*, both of which are made moveable for that purpose.

The end of the intended clay retort being thus formed in the nose part of the machine, the plate *k* must be removed from the nose, when, on forcing the piston *g* forward, the plastic clay will be projected out at the end of the nose in the shape and as a continuation of the retort (the end of which had been formed as described) to any length required, in the manner shown by the sectional fig. 3, where it may be received and supported by an endless travelling cloth, or a board and rollers, and the length of moulded clay may then be cut off by a wire in the ordinary way, and sent to the drying place.

Another form or modification of this machine is shown in longitudinal section at fig. 4, in which, instead of the nosepiece above described, a D-formed hoop, *l*, *l*, or of any other required figure, is introduced as a die, which, in commencing the operation of making the end of the clay retort, must be kept in its place, and the front of the cylindrical box closed by a plate, *k*, as before. The core, *c*, formed to the desired internal figure of the retort, is in this instance made fast to the piston, *g*, and advances with it. When the end of the retort has been made as before described, the plate, *k*, must be removed, and on now projecting the clay forward it will assume the moulded form shown in the front view, fig. 5, and in the section, fig. 6. in which the plate, *k*, is removed. Under some circumstances the patentee

proposes to use (instead of the machinery above described) peculiarly constructed hand moulds, shown at figs. 7 and 8, for the formation of clay retorts.

These moulds may be made either of wood, metal, or plaster, in two or more parts, according to the size and figure required. Fig. 7 shows a top view of one of the moulds of a D form, which is the shape most commonly used. The mould is curved at *a*, *a*, the part which is to constitute the roof or top; the bottom, *b*, is a flat plate, capable of being detached, which is best suited to this form, and to ordinary-sized retorts. The two, or it may be more, parts of the mould, when combined, are to be made fast by external bracings of iron hoop, *c*, *c*, with a bar, *d*, keyed or screwed thereto; or, if the mould is made of plaster, rope bracings will suffice.

In commencing the operation of moulding a clay retort by means of this apparatus, the interior of a single mould is uniformly worked over, by hand, with a substantial coating of the clay; the clay is then beaten down to any required uniform thickness, which may be from about 2 to 4 inches. When the first mould has been thus coated, and so much of the clay retort shaped and finished, a similar mould is to be placed upon the top of the former, their edges perfectly coinciding, and they are then to be bolted together. This being done, the interior of the second mould is coated with clay, in like manner to the first, taking care that the plastic clay of the second operation shall be perfectly united with the edges of that produced in the former mould. In this manner the retort may be continued to any length, by erecting one mould upon another, and carefully joining them as shown at fig. 8. In some cases it will be found desirable to line the internal parts of the moulds with flannel or cloth, to prevent adhesion.

It may be necessary for the moulds to remain upon the moulded retort for some hours, in order that the clay may become perfectly stiff before they are removed; but of this no precise instructions can be given, as it will vary, and must depend upon the consistency or stiffness of the materials used.

The patentee claims, firstly,—the introduction, or mixing of carbonaceous matters with the clay, previously to its being moulded into retorts for generating illuminating gas; secondly,—the novel kinds of moulds and machinery for forming retorts of clay and other earthy materials, intended for the generating of gas, as above ascribed.

MACHINE FOR MAKING SANITARY PIPES.

The drawing on the following page represents a machine used for making sanitary pipes, by Messrs. Wm. Harriman and Co., of Blaydon-on-Tyne.

The machine is known as "Spencer's patent," and the advantage attending its use may be briefly summarised as follows :—

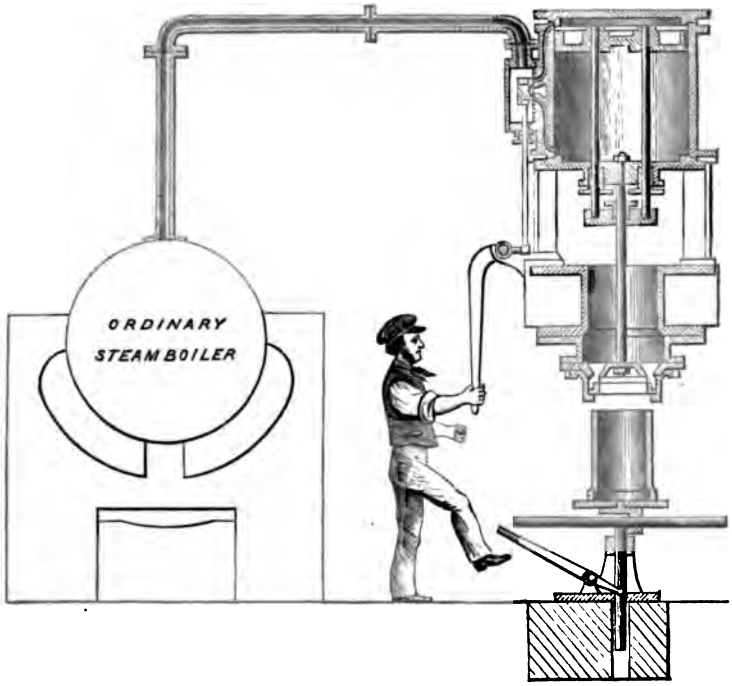
1st.—The *quickness with which pipes are made*, as also their smoothness and perfection.

2nd.—The *making of the socket in combination* therewith in a moment.

3rd.—The consequent *time and room saved* in any manufactory by not having to wait or remove for socketting.

4th.—The *method of making bend pipes* from the machine, avoiding the expense and lumber of plaster moulds—especially where many radii are required for each diameter of pipe, and also getting nearly as many out of hand as straight pipes—very important in case of urgency, which often occurs.

5th.—The great economy of *making junction pipes*, whether for square, oblique, or curved.



STATISTICS OF THE VALUE OF THE VITREOUS AND CERAMIC MANUFACTURES.

VALUE OF THE GLASS MANUFACTURES.

Plate glass	£80,000
Crown, sheet, and and coloured glass	95,000
Flint glass	200,000
Bottle glass of all kinds	263,000
Total value	£638,000

VALUE OF THE EARTHENWARE.

On the Tyne	... ...	£100,000
„ Wear	... ...	40,000
„ Tees	... ...	50,000
	Total value	£190,000

VALUE OF FIRE-CLAY GOODS.

80,000,000 fire-bricks, worth	... ...	£160,000
12,000 fire-retorts, worth	... ...	24,000
50,000 tons ground fire-clay, worth	...	20,000
		204,000
175 miles of glazed pipes	... ...	34,650
	Total value	£238,650

ON

THE TEXTILE MANUFACTURES

OF THE DISTRICT.

PAPER MANUFACTURE	...	WM. HENRY RICHARDSON.
CARPET do.	... ...	WILLIAM HENDERSON.
HAT do.	... ...	WILLIAM WILSON.
ROPE do.	... ...	G. LUCKLEY.

N.B.—The Editors regret that they were not successful in finding any gentleman connected with the Woollen Trade, who had leisure to prepare a Report on that Manufacture.

ON

THE MANUFACTURE OF PAPER.

BY

WILLIAM HENRY RICHARDSON.

In consequence of the general disinclination on the part of paper manufacturers to furnish any information or statistics of their operations, this account will necessarily be imperfect.

The estimates given have, however, been carefully considered, and are as accurate as possible under the circumstances.

Number of firms in the trade	12
„ machines making white paper	10
„ „ brown paper	9
	Tons.
Quantity of white paper made per year	3,500
„ brown „	4,500
Total	8,000

being about one-twelfth of the entire production of the United Kingdom.

Total estimated annual value	£300,000
	Tons.
Coarse materials, as old rope, &c., used for brown paper	5,200
Rags	4,000
Esparto grass	2,000
Bleaching powder	400
Soda ash	200
Coals	35,000

IMPORTS OF ESPARTO GRASS TO THE PORT OF NEWCASTLE-UPON-TYNE.

	Tons.
1860	1,224
1861	2,613
1862	9,534

In 1838, the date of the former meeting of the British Association in Newcastle

The number of firms in the trade was	13
„ machines making white paper	5
„ „ brown paper	10

Estimated quantity of paper made, 4000 tons per annum.

Several small country mills have since that time become extinct; and, as may be seen from the figures, though the number of firms engaged in the trade has diminished, the quantity of paper made has at least doubled since that time.

The early history of the trade in the district appears to be involved in great obscurity; and, notwithstanding careful enquiries, only a few particulars have been recovered; part of them are so uncertain that it has been thought best to omit them.

At Haughton Mill, near Hexham, it is said that large quantities of paper were made about the close of the last century, for the purpose of forging French assignats at the instance of our Government, by whom they were circulated on the continent, with a view of embarrassing the financial operations of the Revolutionary Government.

In 1825–6, when the competition between machine and hand makers of paper became very severe, many of the latter resorted to the expedient of evading the payment of the duty, to enable them to sell their paper without ruinous loss; others were unable to meet their engagements from this cause, and, on failing to pay the excise duty, were, together with their fraudulent traders, imprisoned for non-payment of Excise duty and penalties. To such an extent did this take place, that it has been asserted that, at one time, two only of the manufacturers in the district were at liberty.

The Excise duty, which was first imposed in the reign of Queen Anne, and was finally repealed in 1860, was formerly very vexatious, and interfered with the manufacturers to a monstrous extent. Prior to 1839, the duty was 3d. per lb. on white paper, and 1½d. on brown; and brown paper was by law required to be made of tarred rope only, without extracting the tar therefrom. This, as may be imagined, led to endless disputes between the manufacturers and the Commissioners of Excise. In 1839, this classification was abolished, and the duty was reduced to 1½d. per lb. on all paper, irrespective of quality, and, at the same time, the above restriction, being no longer necessary, was also abolished. The Acts of Parliament under which the duty was levied, which were very numerous and complicated, were, at the same time, consolidated, and all the regulations so modified that the manufacturer was not interfered with, more than was absolutely necessary for the safe collection of the duty.

The abolition of the classification in paper, and the removal of the consequent restriction as to the material to be used in the manufacture,

had an important and special effect on the manufactures of this district, more especially on the brown paper trade. The introduction of jute into textile manufactures a few years previous, had begun to be perceived in the old materials; the large importations of sugar and cotton from the East Indies had also placed large quantities of jute waste and old bagging of this material at the disposal of the paper-maker. The art of bleaching jute was then unknown, so that it could not be used for white paper, and the absurd Excise restriction became especially irksome. As this sort of material was well adapted for making coarse papers; was cheap and abundant; while the substitution of chain for hempen cables for ships some years before, and the introduction of iron ropes into collieries, both for pit ropes and for working railways by stationary engines, in place of hempen ropes, diminished the supply of old ropes, the equalization of the duties was highly beneficial to the trade, allowing the manufacturer to use whatever material he found best adapted to his purpose; and, whilst the best quality of brown paper is still made entirely of old ropes, the inferior sorts are manufactured from a great variety of materials, old railway waggon covers, straw, peat, hop vines, tarpaulins, oil-cloth cuttings, old door mats, and refuse of every conceivable description—if only it has fibre, and is cheap, and is also capable of being beaten into pulp, all are made available. The only common fibre that has hitherto proved intractable is the coir, or cocoa-nut fibre.

The principal improvements that have been made in the manufacture of paper in late years, are in the details and general efficiency of the machinery, whereby a much larger quantity of paper is made with the same apparatus than formerly—and in the superior management of the chemical processes, whereby a material, that formerly was entirely useless, is now worked up into common shop papers; and inferior rags are cleansed and bleached into a good white paper, which formerly were made into coarse paper.

The only notable exception to this, is the introduction of Esparto grass; the importation of which has been steadily increasing, and, as will be seen from the statistics already given, amounted to nearly 10,000 tons in the year 1862, into the port of Newcastle alone, the greater part of which was, however, forwarded by railway into Scotland, Lancashire, and elsewhere.

Newcastle affords special and peculiar facilities for the importation of this material from the east coast of Spain, where it is principally gathered. Vessels load at Newcastle with coke or coal for Spain, and

bring, in return, cargoes of manganese, pyrites, copper ore, lead and lead ore, iron ore, and other materials for the use of the chemical and other manufactures on the Tyne; and from the lightness of the Esparto grass, one ton of which occupies the space of 3 to 4½ tons measurement, they are enabled to carry a full cargo of it, in addition to the minerals which come as ballast, thus materially economising the cost of freight— so much so, that paper manufacturers near Edinburgh and in Lancashire find it cheaper to import *via* Newcastle than by way of Leith or Liverpool.

Esparto, or alfa, as it is called on the African coast, is a coarse grass which grows in sandy places, in almost all the countries bordering on the Mediterranean. This grass consists mainly of *lygeum spartum*, *stipa*, *tenacissima*, and other species of the last-named genus all very similar in character and general appearance.

It has been used from time immemorial for making mats, ropes, &c., and is mentioned in Pliny's Natural History as applied to these purposes.

The following is from Dr. Holland's translation:—

"Spart verily was not known before the first voyage and expedition that the Carthaginians made in a warlike manner into Spaine. An herbe this is also, growing of itselfe, without setting or sowing (which indeed it cannot abide). Full well and properly it might be called, the rush of a dry and leane ground, and a very defect or imperfection appropriate to that countrey alone of Spaine: for, to say a truth, it is the fault and badnesse of the soile in the highest degree, that breedeth it, and where it commeth up nothing else can be sowed and set or will grow at all. That in Affricke or Barbary is very small and good for nothing. In the territory of New Carthage or Cartajena (which is in the higher part of Spaine) it groweth much: howbeit all that tract is not given to breed it, but look where it commeth up, you shall see whole mountaines all overspread and covered with it. Hereof the rusticall peasants make their mattrases and beds; this is their fewel wherewith they keep fires, of it they make their torches and links to give them light, with it they are commonly shod, and the poore sheepheards clothe themselves therewith.

"Howbeit, hurtful is this plant to cattell, unlesse it be the tender tops and crops of the branches, which they may brouse and eat without harme. For other uses, when the Spaniards would plucke it up, they have much adoe withall and a great toile about it, for their legs must be wel booted as it were with grives, their hands covered with thick hedging-gloves, as gantlets; and being thus armed at all points, yet they lie tugging at it, pulling, writhing, and wresting the same with hooks and crooks either

of bone or wood, until they have their will of it. Come they about this work in winter time it is in manner impossible to get it up, but from the Ides (*i.e.*, the mids) of May unto mid June, it is very tractable; for this is the time and season when it is ripe, and then commonly they gather it for their ordinary uses before named. Being once pulled and sorted, the good from the bad, it is made up into bundles and faggots with the life still in it, and so piled on a heap for the first two daies, the third day they unbind it, lay it loose and scattering in the sun for to be dried, which done, they make it up againe into faggots, and so bring it in, and lay it up within house.

"After all this, they steep it in sea water (for that is best) or else in fresh, for want of the other; after this watering it must be dried in the sun, and then steeped in water a second time, but if a man had urgent occasion to use it presently out of hand, he must put it in a great tub or bathing vessel and let it soke there in hot water a time. Now if when it is dried againe, it be stiffe and will stand alone, they take it for a sure signe that it is sufficiently watered, and hath that which it should have. This is a very neere and ready way, and saveth them much labour. Thus being prepared one of these two waies, it ought to be brayed and betten before it will serve the twine, and then no cordage in the world is better than that which is made of it, nor lasteth so long in the water, and the sea especially, for it will never be done. For drie werke, I confesse, and out of the water, the gables and ropes wrought of hemp are better, but spart made into cordage will live and receive nourishment within the water, drinking now the full as it were to make amends for the thirst which it had, in the native place where it first grew. Of this nature is spart besides, that if the ropes made thereof be worne and (with much occupying) out of repaire, a little thing will mend and refresh them, yea, and make them as good as ever they were, for how old soever it be, yet will it be wrought very well again with some new among. A wonderfull thing it is to consider and look into the nature of this herb, and namely how much it is used in all countries, what in cables and other ship-tackling, what in ropes for masons and carpenters and in a thousand necessities of this our life. And yet see the place which furnisheth all this store, lying along the coast of New Carthage, we shall find to be within the compasse of 30 miles in bredth, and lesse somewhat in length, and verily if it were fetched farther off within the main, the cariage would not quit for the cost and expenses."

This account, written above 1,500 years ago, was correct and nearly

complete until the year 1860, when Esparto began to be largely imported into the Tyne for paper-making.

Various attempts have been made to manufacture Esparto into paper during the last 30 years, one patent for the purpose being dated as far back as 1839; and in France similar efforts have been made for many years.

None of these, however, have been practically successful on a large scale, with the exception of the process arranged by Mr. Thos. Routledge, of Eynsham Mills, in Oxfordshire, who has been making printing paper from Esparto for the last nine years, and has taken out three patents for the processes employed. He has lately taken a mill at Ford, near Sunderland, for making printing paper from Esparto only. Other manufacturers, have, however, used it mainly as a blend with rag material.

No material alteration in the machinery or apparatus is required for working Esparto, and very much less power is required. The successful working of this fibre depends mainly on the careful and proper adjustment of the quantity and strength of the chemicals employed.

The following analysis of Esparto is taken from the "Journal des Fabricants de Papier," and annexed thereto is a statement of the composition of flax straw, and of wheat straw :—

	Esparto.	Flax Straw.	Wheat Straw.
Fibre unbleached	73·5	...... 12·5	
Gum, resin, and colouring matter	25·1	...... 86·044	... 95·96
Non-fibrous woody matter, as the joints of straw and shive of flax	0·0		
INORGANIC MATTER.			
Soluble and insoluble salts ...	0·695	1·156	...... 1·38
Oxide of iron	0·879	·1	...... ·04
Silicia	0·326	·2	...... 2·62
	100	100	100
Produce in paper, per cent. ...	50 to 52	10 to 11	35 to 40

The quantity of soda ash required for neutralizing the gummo-resinous matters in the fibre, so as to admit of its being made into a pulp, is very large, though not so great as is required for straw, and the fibre, unlike rags, never having before been subjected to bleaching or other chemical treatment, also requires very much more bleach powder to bring it to a colour suitable for printing paper. The quantities required are from 5 to 6 times as much for cleansing and bleaching the coarsest rags.

The importations of Esparto into the United Kingdom for the past twelve months being about 18,000 tons; the use of this article may be estimated to have caused an increased consumption of soda ash and bleach powder of at least 4000 tons per annum, and these chemicals being dear on the Continent of Europe, is one obstacle to the use of Esparto there. Nearly all newspapers, not excepting that on which the *Times* is printed, contain a portion of Esparto, and some of the penny daily papers published in Edinburgh, contain only one-fourth rag material.

The large supply of paper-making material from this source has been most opportune; rags are becoming gradually scarcer; coloured rags, suitable for making common printing paper, were worth 4s. to 6s. per cwt. in 1848, and are now worth 9s. to 12s. per cwt., and this notwithstanding the relief produced by the importation of Esparto.

This scarcity—the existence of which the Jurors' Report of the Exhibition of 1862 most unaccountably denies—has been aggravated by the almost total cessation of the supply of waste and tares from the cotton mills; and even with the assistance of Esparto grass, and cheaper chemicals and fuel, the paper-makers in this country have been placed in a most disadvantageous position in respect of the supply of material, in comparison with their continental rivals, by recent legislation, which, in the opinion of many, will have a tendency to cripple the progress of the trade in this country. The discussion of this subject is, however, not suited for the present occasion.

The greater part of the paper manufactured in this district is of the coarser description, and Newcastle browns, and Tyne casings, which, from a geographical error, are known in Manchester as Scotch paper, have a reputation throughout the kingdom for toughness and general excellence.

The printing and writing papers of Messrs. Annandale and Son have a deservedly high reputation in the London Market. The other description of white paper made in the district, is mainly for the daily newspapers, whose consumption of common printing paper has of late years become so enormous as materially to alleviate the depression consequent on the general dullness of trade arising from the cotton famine, and it is hoped that notwithstanding the unfairness with which the trade has been treated by the Legislature, that with the resumption of business in Lancashire, it may recover its former prosperity.

ON THE

MANUFACTURE OF CARPETING.

BY

WILLIAM HENDERSON.

The woven fabrics made in the district of the Tyne, Wear, and Tees, are few. Some years ago canvas and sailcloth were woven on the banks of these rivers, but now the chief manufacture is carpeting. The principal seat of this manufacture is in the city of Durham, and it formerly flourished extensively at Barnard Castle, Darlington, and Bishop Auckland.

Before proceeding to notice carpeting as an article of commercial industry, it will be interesting to pass in review the origin, progress, and existing attainment of the trade. One of the most ancient looms yet in existence is that of the Hindoo, and to this day the carpets of the East woven in these primitive looms are held in high and deserved estimation. To Englishmen accustomed to have the manufacture of woven fabrics assigned to numerous classes of artizans, each performing but a fragment of the whole, it seems singular to learn that the Persian peasant and his wife still control the arrangement of the quality, design, colors, size, and finish of the carpets manufactured in their poor cottages, and it is not without some sense of humiliation that our manufacturers yet turn to the carpets of these poor peasants for many hints of design and coloring to be introduced into the latest and most récherché of their season patterns.

To the Mahommedan the carpet is a necessity; he spreads it on the ground before petitioning his Prophet, and even the poorest endeavour to cover their best rooms whenever strangers are to be welcomed, or friends attracted to the social gathering. The early history of carpets in the East is so uncertain as to be lost in obscurity. They were first introduced into Europe by the Moors when they held possession of Spain, and also by the Venetian Republic, who, by retaining for centuries the monopoly of the Turkish trade, found its own interest in dealing in this

luxury, which was soon adopted by christian communities, and used to adorn the palaces of the western nobility.

The exigencies of climate and the demands of luxury and taste in our country appear to have called carpets and hearth rugs into use as early as the fourteenth and fifteenth centuries.

From the covering of walls with exquisite tapestry of needlework the transition was very natural to the production of skilfully-wrought effects in covering for floors. As the power and wealth of the middle classes became sensibly developed under the successive sway and prosperous encouragement afforded by the Tudor sovereigns, the demand for specimens of foreign and continental workmanship increased. We accordingly find that in the reign of our first Stuart monarch the method of weaving Tapestry for walls and floors was introduced into this country as practised in Flanders, then the chief seat of skilled textile labour throughout Europe.

Carpet-making from this date ceased to form a considerable feature in the occupation of our great domestic or conventual establishments under the head of *needlework*, and we may henceforth consider it as a branch of industry the importance of which will more fully appear when we trace its settlement at special localities, and identify it under the different kinds by which it is generally known to the public.

Proceeding in regular order from the rise of carpet-weaving under James the First, it would appear that the end of the seventeenth or beginning of the eighteenth century witnessed also the introduction of Kidderminster carpet at the town of that name, in the midland district of England. Kidderminster had, for upwards of four centuries, been distinguished for its woollen fabrics: the peculiar properties and softness of the river water there were supposed to be specially favourable for dyeing and manufacturing purposes. This and other circumstances led to the establishment in that place of an industry which it still retains, and of late years has developed to the extent of becoming its sole trade. It is, however, worthy of note that the kind called Kidderminster carpet is no longer made there, but has been transferred to Scotland, Yorkshire, Durham, and Kendal. The largest manufactory for Venetian carpeting is in Durham.

Brussels carpet has entirely left the capital of Belgium, and forms the staple trade of Kidderminster; *Axminster* carpet has ceased to be made at Axminster, and has been transferred to Wilton, near Salisbury; while the trade in *Wilton* carpets has been attracted to Kidderminster and the North of England.

Turning next to Brussels carpet as the leading fabric in the home trade, we find that in 1745 the Earl of Pembroke induced Flemish workmen to settle in the town of Wilton, and there successfully established the looped-pile carpet, thenceforth called *Brussels*, which was soon followed by the cut-pile fabric, produced by similar machinery named *Wilton*. Both articles were in that same year (1745) taken over to the town of Kidderminster, and so enterprisingly has the trade been followed ever since, that in the last-named town alone about 2,000 hand-looms were required in 1850 to keep pace with the demand for these goods; and at Halifax and Durham machinery and capital were liberally embarked in the same branch of trade.

The uninformed on these subjects must observe that the pattern in *Kidderminster*, *Three-ply*, *Brussels*, and *Wilton* Carpets (those goods in fact which have a design or figure wrought up superficially with indyed worsteds, as distinguished from the printed carpet, we shall hereafter refer to), are all indebted for this to the Jacquard principle; and, generally speaking, these kind of goods exercise an undoubted preference in public estimation over other descriptions for their genuine excellence and durability.

The beautiful and simple process of raising the pattern, called after the celebrated inventor, M. Jacquard, of Lyons, who first applied it to silk-figured goods, was introduced to carpet-making about 1830, and by its less complicated system of working and economy of time and material rapidly superseded the cumbrous method previously used for the purpose. The decennial period extending from 1840 to 1850 was characterized not only by the greatest number of original inventions in carpet fabrics, but also by the skill and ingenuity with which motive steam power was employed to perfect the make, and cheapen the cost, of all looped and cut-pile goods. Thus, in time, steam power entirely superseded the appliances of hand labour—both in the older Jacquard looms and in the printed goods of a more recent introduction.

Printed tapestry carpets, patented by Mr. Whytock in 1832, and woven in hand looms, first gave the public the advantage of a cheap and effective floor covering, with unlimited colours and a surface of pile more like the well-known Brussels than any other fabric which had then appeared.

The warp by being formed of a number of threads (each in the first instance separately printed upon with an injected dye) admitted of facilities in design and colors unknown even to Jacquard goods, though inferior to them in distinctness when completed in carpet.

The invention realized the expectations formed, and when it passed from the inventor's hands into those of Messrs. Crossley, of Halifax, the imperfections were so far mastered that the carpet soon assumed an important position in the trade, and by the year 1850 some 700 or 800 looms were engaged upon it. Imitations more or less ingenious in the way of *surface-printed carpets* soon followed at Rochdale and elsewhere, but after a brief run most of them sunk into oblivion; the most important result in this race for cheapness being the application of steam power to this class of carpets.

The invention and application of steam power has done so much towards placing the luxury of carpets within the reach of all classes, and also in improving the wages, and consequently altering the habits, of the workmen, that it will require a further notice as to its origin, growth, and the extent of its application to the carpet fabrics of the United Kingdom.

Power-loom weaving was first applied about the year 1847 to the manufacture of tapestry or printed carpets (though only experimentally at that time) by Messrs. John Crossley and Sons, of Halifax. The first patent for weaving Brussels carpets by power was taken out by Mr. Wood, of Pontefract, in 1842, and to him the merit is undoubtedly due of the earliest movement in this country in endeavouring to supply mechanical movements in the weaving of their goods for the hitherto severe drudgery of the hand craftsman. The practical utility of his invention seems to have lain dormant for some years, for although Messrs. Crossley of Halifax, who were occupied in working the tapestry power-loom, became the purchasers of Wood's patent, yet it was not until the appearance of Mr. Bigelow's specimens of Brussels carpet woven by power-looms in 1851 that full attention was really bestowed on the subject. Mr. Bigelow, of the United States, submitted at the 1851 Exhibition results in power-made goods which, coupled with his statements of large saving in cost, attracted great attention, and induced Messrs. Crossley to become the purchasers of the whole of his patents for this country; and this firm has since licensed the leading Brussels Carpet manufacturers with this loom, being the same as is currently worked in the trade. Several valuable improvements were afterwards added, affecting chiefly the regularity of the surface and more rapid execution of the work, and the result of the whole in carpet-weaving may be briefly described as follows:—Under the old hand-loom system a good workman well supplied with materials could average 4½ yards a day, or 27 yards weekly, of the then ordinary hours of labour, and he required the constant assistance of

a boy or helper to raise the warp-threads and place the rotating cards in order in the Jacquard cylinder. Now, in 1863, the same workman, with fewer hours of employment, superintends a machine which will turn off, under fair condition of material and good management, an average of 27 yards daily, a quantity six times as much as by the old process, and that with far less personal fatigue, and at a much more remunerative price for his labour. It is not too much to say that great as are the advantages reaped by the public in constantly replenishing their carpet requirements by the direct saving of sixpence per yard, which the manufacturer has been enabled to make in the first cost between carpet woven by hand and power, and of which the public has the benefit, yet the condition of the carpet operative has no less sensibly improved by the change of system. The old evils attendant upon decentralized labour, with its irregular hours and uncertain employment, so long as the hand-loom formed the adjunct of the cottage or the weaving shop, have not been without their significant effect in Coventry and Spitalfields, and precisely the same result in a scarcely less mitigated form was to be found in the seats of carpet industry in Durham and elsewhere. As soon, however, as steam-power looms appeared, suitable erections were needed, and concentration became the order of the day.

The Factory Act, which interposes a wise and salutary check on the employment of young persons, was needed in this trade. When introduced it placed carpet-weaving on the same footing as other industrial occupations in this country which are governed by motive power, and so far reconstituted the entire relations between labour and capital. "Again the tendency has been materially to improve wages."

According to a Parliamentary return of hand-loom wages, some 25 years ago, the average earnings of all carpet-weavers scarcely reached 15s. a week, whereas the generality of workmen will, by superintending a carpet power-loom for 60 hours per week, make 25s. per week, and that without the physical exertion and constant strain of bodily powers which was necessary under the old system. It is, however, to be regretted that the remuneration of hand-loom weavers is still insufficient for their proper maintenance and standing in society. A recent investigation at several factories showed that the wages of weavers of super Kidderminster carpeting only averaged 15s. per week. On representation, the English masters in December, 1863, advanced the rate by 10 per cent.

Besides Brussels and Wilton carpeting, two other kinds are extensively manufactured in Durham.

The Venetian carpeting is produced in a simply-constructed loom,

the pattern frequently being only two stripes of coloured warp, and so depending entirely on taste in the arrangement of the shades: sometimes it is made in small diaper or tesselated pattern; in these cases the warp is arranged by the weaver in the gear.

Durham has had the chief part of this manufacture for the past 25 years. The Kidderminster carpeting has a worsted warp with woollen weft, and the pattern is made by the combination of the colours of each; the outline of the pattern is arranged by the Jacquard machine, and the cloth is two-ply united by this outline. It has an advantage over the Brussels and tapestry kinds in having the pattern on both front and back—thus allowing the carpet to be turned when necessary.

The records of the city of Durham furnish some particulars of the early existence of cloth-making carried on there. It is stated that a Mr. Henry Smith granted to the aldermen and burgesses by will, dated 20th July, 1598, all his coal mines, then of the clear yearly value of £100, besides a personal estate in money, debts, and goods, beyond debts and legacies worth £600, unto the City of Durham, in these words:—"And "as touching my colemynes, and that the increase thereof may be employed "for the benefit of many, I freely give them all to this City of Durham, and "the cause why I doe soe, and further, as followeth is, that some good trade "may be devised for setting of the youth and other idle persons to work, as "shall be thought most convenient whereby some profit may arise to the "benefit of the said City, and reliefe of those that are past work."

The undertaking seems, from its infancy, to have been a prey to legal difficulties and dishonesty. In 1612 the governors purchased for the sum of £150 a large building called the "New Place," which had formerly been the Palace of the Nevill family, and here they established Henry Doughty and William Bastoe as cloth-workers—£200 being loaned them with which to provide materials. In 1614, £250 more was embarked in the concern, which, however, only went forward for two years, and then collapsed. "The governour then employed Thomas Browne and George Beecrofte, two new cloth-workers, and bought them in wool, and gave them it to work," but the work went on to no good purpose, and in 1619 was discontinued. The income arising from the trust was from that time paid to the poor of the city, and to the placing of apprentices at trade. This practice is still followed. The governors had, however, invested a portion of the capital in premises situated near the river, and adjoining the "New Place," and these being convenient for manufacturing purposes attracted the attention of Mr. John Starforth, who, in 1780, commenced the manufacture of tanning cloth, a coarse worsted fabric of narrow width,

dyed in self-colours, and used for women's dresses and petticoats. He also manufactured a few Kidderminster and Venetian carpetings. Considering the time when this concern flourished it was of great extent, and exercised a most important influence in the city and neighbourhood; upwards of 100 woolcombers and 700 weavers were employed, the former worked upon the premises of their masters, but the latter, with few exceptions, had their looms at their homes. The wool, which was chiefly the "long wool" of the district, was, when combined, sent to the villages for at least ten miles round the city, and there spun into worsted by the peasantry on what were termed "slab wheels:" each wheel was worked by one person, who had to perform the very difficult duty of spinning an even-surfaced thread to a particular number or weight: the yarn spun on being brought to the factory was dyed and wove into Tammy and Calamanco cloths. In the early part of the present century a large trade was also conducted in Durham, and doubtless in the other towns of the county, in weaving muslins, ginghams, and shirting cloth, the warps and wefts for which were sent ready dyed from Manchester and Carlisle. The management was carried out by agents sent from these places. The practice of having looms in their dwellings led to that peculiar feature which may yet be noticed in many of the older streets: a square outshot window was projected from the lower story or sitting-room almost sufficient to hold the loom, and thus the inconvenience of its presence was mitigated.

Mr. Starforth became bankrupt in 1806, when the distressed state of the unemployed weavers, and the empty premises, tempted no fewer than five firms to engage in the manufacture of carpetings. Mr. M. Oliver had 18 looms, Mr. Wm. Cooper 18, Mr. James Bell 4, Mr. J. Waddington 3, and Mr. Wood 12. A deficiency of capital soon brought all these firms to ruin, and in 1814 they had ceased to exist.

Mr. Gilbert Henderson, who originated the firm in Durham, now known as Henderson and Co., first commenced his manufacture of carpeting at the small village of Church Merrington, with 14 looms. The vacation of the premises held by Mr. Oliver and Mr. Cooper tempted him to Durham, and in May, 1814, he transferred his business to that city. The first incident worth noting was a severe strike of the workmen, which occurred in 1819, and continued for six months. This was put down by the firmness of Mr. Henderson, and the business continued to prosper till his death in 1824, when it passed into the management of his eldest son, Mr. John Henderson. In 1820 two Brussels looms were obtained from Kidderminster—these were the first that had been permitted to leave that town, and the person who brought them durst not for many years return

to the place, so violent was the feeling against any one contributing to destroy the monopoly of Kidderminster in the manufacture of Brussels. In 1828, and again in 1832, considerable additions were made by Messrs. Henderson and Company to their power of manufacturing this class of goods, but the greatest impetus to their trade, both in these and Kidderminster carpetings, was given by their adopting for their exclusive purposes the assistance of an excellent artist. The high standing the firm thus early obtained for excellence of design has never been lost; and in the competition at the International Exhibition of 1862 they were one of the only four firms who obtained medals for " excellence of design, colour, and manufacture of Brussels."

In 1837 they effected economy by erecting chipping and rasping machinery for dyewoods—for which, previously, they had to depend on drysalters. In 1851 their large hand-loom weaving shed was erected, in which are 121 looms, with some preliminary processes; and, seizing on the first opportunity for introducing weaving by power, they, in 1854, erected their steam power-loom weaving shed, which has since been extended to accommodate 49 looms. These two sheds are the loftiest and best built in the carpet trade.

The old spinning mills of the factory were burnt to the ground in 1859, and have been re-built on a larger and improved plan; the dye-houses, &c., were also re-built and extended a few years since, so that the factory may be said to be nearly all recently erected.

In 1859, and in 1860, Messrs. Henderson took out patents for a new power-loom for weaving Brussels, by which a considerable increase is obtained in the production of best 5-frame Brussels, whilst the weaver earns a higher remuneration at a less charge per yard for his labour,—the increased production is, on an average, 17½ per cent., and the economy in wages 6½ per cent.

No certain record exists of the commencement of carpet manufacture in Darlington; the concern which for long associated its name with the trade, was commenced by Mr. Kipling in 1813, and continued to expand under the management of himself and sons until 1845, when it had about 50 looms in work. Its chief manufacture was Venetians, and these were celebrated for the neat appearance of the cloth and the good taste exhibited in colouring. The business was abandoned in 1855. Two or three smaller firms have also, within the last few years, followed the business in Darlington, but without success; their works are now (1864) all closed. Messrs. Green became insolvent in 1863.

Barnard Castle for several years exercised a very important influence

upon the carpet trade of London and the kingdom generally. About the year 1815, Mr. Thomas Crampton, who had previously manufactured plaid and stuff goods, started the first carpet loom; it was a happy period for the experiment, and his prosperity was so evident that several of his fellow-townsmen also embarked in the trade.

Notwithstanding the inexperience of these firms some of them were successful; and in 1836 there were no less than seven firms, having upwards of 400 looms. The following is believed to be a tolerably correct estimate of the number of looms possessed by each firm in that year:—

Messrs. Monkhouse	130
Mr. Pratt	80
Messrs. Atkin and Co.	60
Messrs. Dunn and Ramshaw	54
Mr. Raine	36
Mr. John Winskill	38
Mr. J. Winskill	30
Total	428

From that time the trade declined, and it is now represented by one firm of about 20 looms. It is obvious that so rapid a declension of this large trade must have arisen from powerful causes; and these may be readily found—1st. In the heavy expense of carriage: Barnard Castle not having the advantage of cheap transit by either sea or rail. 2nd. In the manufacturers being content to follow in the footsteps of other firms, seldom originating new patterns; and 3rd, in allowing themselves to enter too heartily into the competition of low prices—neglecting the maxim that a good article will eventually gain a good price; this cause no doubt was a necessity to some firms whose capital was limited. At one time, Messrs. Monkhouse had a name for manufacturing handsome saleable goods; and some of the other firms made varieties which were not without merit.

In the report of the jurors on the carpets shown in the Exhibition of 1862 the value of the annual production of England and Scotland is estimated at £2,110,000, as detailed below. This report was drawn up by Mr. Brinton, a juror and manufacturer at Kidderminster:—

Yorkshire	£980,000
Kidderminster and neighbourhood...	630,000
Durham and Kendal	120,000
Somersetshire and Wiltshire	40,000
Scotland	340,000
	£2,110,000

The report further states that the number of persons employed in the manufacture of carpets and the preparation of materials for them is about 40,000.

TABLE No. 1,

Showing the Number of Firms engaged in the Manufacture of Carpeting, and Looms for each description of Carpeting, in the several Counties of England in the year 1850.

COUNTY.	No. of Firms	Brussels Hand Looms.	Printed, Tapestry and Table Cover, &c. Hand Looms.	Patent Axminster Carpet and Rug Looms.	Three-ply and 4-4 Kidderminster Carpet Looms, either Common or Super.	4-4 Dutch Looms.	Venetian and Damask Looms.
Durham	7	76	......	......	277	......	262
Lancashire	1	......	93 Sevier's Ptnt	......	......	......	......
Lincolnshire	1	......	......	......	30	......	......
Middlesex	1	17	......	......	5	......	8
Shropshire	3	149	6	......	3	......	34
Somersetshire ...	...	......	......	......	......	......	......
Westmoreland...	1	20	......	......	76	6	8
Wiltshire	1	21	......	......	......	......	......
Worcestershire..	29	1984	310	22	55	17	67
Yorkshire	22	37	594	......	641	196	29
	66	2304	1003	22	1087	219	408

TABLE, No. 2,

Showing the Number of Firms engaged in the Manufacture of Carpeting, and Looms for each description of Carpeting, in the several Counties of England in the

Page 237—In Table No. 2, *for* "Patent Axminster Power Looms," *read* Patent Axminster Hand Looms.

[illegible]								
Shropshire	1	10	25	......	......	......		
Somersetshire ...	1	15	......	......	......	18	......	20
Westmoreland...	1	20	......	......	......	83	11	15
Wiltshire	1	33	......	......	......	......	......	...
Worcestershire..	22	255	437	24	149	......	......	11
Yorkshire	28	2	115	713	......	1072	282	71
	60	337	618	815	149	1293	293	250

TABLE, No. 3,

Showing the Number of Firms engaged in the Manufacture of Carpets, and Looms for each description of Carpeting, in the several Counties of Scotland in the year 1850.

COUNTY.	No. of Firms	Brussels Hand Looms.	Printed, Tapestry and Table Cover &c. Hand Looms	Patent Axminster Carpet and Rug Looms.	Three-ply and 4-4 Kidderminster Carpet Looms, either Common or Super.	4-4 Dutch Looms.	Venetian and Damask Looms
Aberdeenshire ..	1	24	......	......	132	12	......
Ayrshire	7	90	......	......	429	6	2
Dumfriesshire...	1	......	......	......	52	......	......
Edinburgh	2	......	160	......	7	......	2
Lanarkshire	5	63	93	180	372	......	......
Renfrewshire ...	2	......	43	......	......	......	......
Stirlingshire ...	4	24	......	......	151	......	12
	22	201	296	180	1148	18	16

TABLE, No. 4,

Showing the Number of Firms engaged in the Manufacture of Carpeting, and Looms for each description of Carpeting, in the several Counties of Scotland in the year 1863.

COUNTY.	No. of Firms	Brussels Hand Looms.	Brussels Power Looms.	Printed, Tapestry and Table Cover, &c., Hand and Power Looms.	Patent Axminster Carpet and Rug Looms, Hand and Power.	4-4 Kidderminster Carpet Looms, either Common or Super.	Venetian and Damask Looms.
Aberdeenshire ..	1	......	......	......	......	109	......
Ayrshire	6	......	21	......	......	487	2
Dumfriesshire...	...	......	......	......	......	......	......
Edinburgh	2	......	......	84	......	6	1
Lanarkshire	5	......	15	......	432	101	......
Renfrewshire ...	...	......	......	......	......	......	......
Stirlingshire ...	3	24	......	......	......	129	12
	17	24	36	84	432	832	15

TABLE No. 5, *showing the Number of Yards, and Value, of each description of Carpeting manufactured in the several Counties of England in the year* 1850.

COUNTY.	Yards of Brussels and Velvet Pile Carpeting, with value at 4s. 1d. per yard cash.	Yards of Printed Tapestry Carpeting with value at 2s. 6d. per yard cash.	Patent Axminster Carpets and Rugs, estimated at a production of £180 per loom per annum.	Yards of Three-ply and Kidderminster Carpeting, with value at 2s 6d. per yard cash.	Yards of Dutch Carpeting with value at 2s. per yard cash.	Yards of Venetian and Damask Carpeting, with value at 2s. 3d. per yard cash.	Total Number of Yards.	Total Value.
Durham	106,704	......	......	518,544	......	980,928	1,606,176	£
	£21,785	......	......	£64,818	......	£110,354	......	196,957
Lancashire ...	......	783,432	......	......	......	......	783,432	
	......	£97,929	......	......	......	......	......	97,929
Lincolnshire ..	......	......	......	56,160	......	......	56,160	
	......	......	......	£7,020	......	......	......	7,020
Middlesex ...	23,868	......	......	9,360	......	29,952	63,180	
	£4,873	......	......	£1,170	......	£3,369	......	9,412
Shropshire ...	209,196	9,360	......	5,616	......	127,296	351,468	
	£42,710	£1,170	......	£702	......	£14,320	......	58,902
Somersetshire	......	......	......	......	......	......	......	
	......	......	......	......	......	......	......	
Westmoreland	28,080	......	......	142,272	26,208	29,952	226,512	
	£5,733	......	......	£17,784	£2,·20	£3,369	......	29,506
Wiltshire	29,484	......	......	......	......	......	29,484	
	£6,019	......	......	......	......	......	......	6,019
Worcestershire	2,785,586	483,600	......	102,960	74.256	250,848	3,697,200	
	£568,713	£60,450	£2,860	£12,870	£7,425	£28,220	......	680,538
Yorkshire......	51,948	926,640	......	1,199,952	856,128	108,576	3,143,244	
	£10,606	£115,830	......	£149,994	£85,612	£12,214	......	374,256
Assumed value of Mosaic carpets made at Halifax							......	2,550
Do. Axminster do. made at Wilton							......	4,500
							9,956,856	1,467,589
Deduct 10 per cent. for holidays and looms not working ...							995,685	146,758
							8,961,171	1,320,831

TABLE No. 6.—ENGLAND, 1868.

COUNTY.	Yards of Brussels and Velvet Pile Carpeting	Yards of Printed Tapestry Carpeting	Patent Axminster Carpets and Rugs	Yards of Three-ply and Kidderminster Carpeting	Yards of Dutch Carpeting	Yards of Venetian and Damask Carpeting	Total Number of Yards.	Total Value.
Durham	284,232	......	......	129,168	......	314,496	727,896	£
	£58,030	......	......	£16,146	......	£35,380	......	109,556
Lancashire ...	......	657,072	......	......	......	......	657,072	
	......	£82,134	......	......	......	......	......	82,134
Lincolnshire ..	......	......	......	95,472	......	......	95,472	
	......	......	......	£11,934	......	......	......	11,934
Middlesex ...	......	......	......	......	......	149,760	149,760	
	......	......	......	......	......	£16,848	......	16,848
Shropshire ...	185,640	......	......	......	......	33,696	219,336	
	£37,901	......	......	......	......	£3,790	......	41,691
Somersetshire	21,060	......	......	33,696	......	74,880	129,636	
	£4,299	......	......	£4,212	......	£8,424	......	16,935
Westmoreland	28,080	......	......	155,376	48,048	56,160	287,664	
	£5,733	......	......	£19,422	£4,804	£6,318	......	36,277
Wiltshire	46,332	......	......	......	......	......	46,332	
	£9,459	......	......	......	......	......	......	9,459
Worcestershire	3,357,588	202,176	......	......	......	41,184	3,600,948	
	£685,507	£25,272	£19,370	......	......	£4,633	......	734,782
Yorkshire......	792,168	6,006,312	......	2,006,784	1,231,776	265,824	10302864	
	£161,734	£750,789	......	£250,848	£123,177	£29,905	......	1,316,458
Assumed value of Mosaic carpets made at Halifax							......	2,550
Do. Axminster carpets made at Wilton							......	5,500
							16216980	2,384,119
Deduct 10 per cent. for holidays and looms not working ...							1621698	238,411
							14595282	2,145,708

TABLE, No. 7,

Showing the Number of Yards, and Value, of each description of Carpeting manufactured in the several Counties of Scotland, in the year 1850.

COUNTY.	Yards of Brussels and Velvet Pile Carpeting with value at 4s. 1d. per yard cash.	Yards of Printed Tapestry, &c. with value at 2s. 6d. per yard cash.	Patent Axminster Carpeting and Rugs, estimated at a production of £150 per loom per annum.	Yards of Three-ply and Kidderminster Carpeting, with value at 2s. 8d. per yard cash.	Yards of Dutch Carpeting with value at 2s. per yard cash.	Yards of Venetian and Damask Carpeting with value at 2s. 3d. per yard cash.	Total Number of Yards.	Total Value.
Aberdeenshire	33,696	......	......	247,104	52,416	......	333,216	£
	£6,879	......	......	£32,947	£5,241	......	......	45,067
Ayrshire	126,360	......	......	803,088	26,208	7,488	963,144	
	£25,798	......	......	£107,078	£2,620	£842	......	136,338
Dumfriesshire	......	......	......	97,344	......	......	97,344	
	......	......	......	£12,979	......	......	......	12,979
Edinburgh ...	......	249,600	......	13,104	......	7,488	270,192	
	......	£31,200	......	£1,747	......	£842	......	33,789
Lanarkshire ..	88,452	145,080	......	696,384	......	......	929,916	
	£18,058	£18,135	£27,000	£92,851	......	......	......	156,044
Renfrewshire	......	67,080	......	......	......	......	67,080	
	......	£8,385	......	......	......	......	......	8,385
Stirlingshire..	33,696	......	......	282,672	......	44,928	361,296	
	£6,879	......	......	£37,689	......	£5,054	......	49,622
							3,022,188	£442,224
Deduct 10 per cent. for holidays and looms and not working......							302,218	44,222
							2,719,970	£398,002

TABLE, No. 8,

Showing the Number of Yards, and Value, of each description of Carpeting manufactured in the several Counties of Scotland, in the year 1863.

Aberdeenshire	......	......	......	204,048	......	......	204,048	£
	......	......	......	£27,206	......	......	......	27,206
Ayrshire	144,144	......	......	911,664	......	7,488	1,063,296	
	£29,429	......	......	£121,555	......	£842	......	151,826
Dumfriesshire	......	......	......	......	......	......	......	......
	......	......	......	......	......	......	......	......
Edinburgh ...	......	570,336	......	11,232	......	3,744	585,312	
	......	£71,292	......	£1,497	......	£421	......	73,210
Lanarkshire ..	102,960	......	......	189,072	......	......	292,032	
	£21,021	......	£64,800	£25,209	......	......	......	111,030
Renfrewshire	......	......	......	......	......	......	......	......
	......	......	......	......	......	......	......	......
Stirlingshire..	33,696	......	......	241,488	......	44,928	320,112	
	£6,879	......	......	£32,198	......	£5,054	......	44,131
							2,464,800	£407,403
Deduct 20 per cent. for holidays and looms and not working......							492,960	81,480
							1,971,840	£325,923

NOTE.—The return for Lancashire is necessarily in part assumed, as Messrs. J. Bright and Brothers, of Rochdale, declined to give any information as to the number of looms, &c., in their factory.

Hearth rugs, of which the tufts are inserted by finger, are not included in the foregoing tables of production. This branch of trade is pursued by so many small firms scattered throughout the country that it has been found impossible to obtain accurate statistics.

Nothing connected with the carpet trade of the North of England is more worthy of notice than the course which the manufacturers have adopted for the prevention of strikes among their workmen.

Previous to the year 1838 strikes were of frequent occurrence in the district, and the want of any co-operation amongst the masters had ended in their workmen placing them at a serious disadvantage (in respect of wages) with other masters, both in the south and in Scotland. This state of things had existed for eighteen months, when, goaded by necessity, a meeting was arranged by Messrs. Crossley, of Halifax; Cooke, of Millbridge; Whitwell, of Kendal; Monkhouse, of Barnard Castle; and Henderson, of Durham.

It was then determined to form an Association for the better regulation of wages in the northern counties. Invitations were issued to all the manufacturers, who with scarcely a single exception attended and gave their adhesion to certain rules for the guidance of the Association.

It was determined that the policy of the body should be not to look solely to the financial interests of the masters but also to consider and, as far as possible, legislate for the benefit of the workmen, always bearing in mind that it was but fair that the operative should have a remuneration for his labour sufficient to maintain himself and family in decent comfort, and to make provision for periods of sickness.

From 1838 to 1849 the Association was presided over by Mr. John Howard, of Leeds; since that time its president has been Mr. William Henderson, of Durham, and its treasurer Mr. John Crossley, of Halifax. The present secretary is Mr. W. Armitage, of Heckmondwike, and these three, assisted by a committee of four manufacturers, attend to any urgent or special matters which cannot be deferred till the annual meetings. The masters assemble each year in the month of July (generally at Leeds), and after the formal business and election of officers for the ensuing year, the chairman states the several topics to be brought forward.

With a view to prevent hasty legislation, a statement of all changes desired by the workmen must be sent to the President fourteen days previously; this is immediately printed, and a copy sent to each master: they have thus ample time for fully considering the several topics. After a short preliminary discussion the deputation from the workmen is

admitted. They present a memorial in which their wishes are stated and supported by short arguments. This is followed by a series of speeches from the deputation, each deputy taking a particular portion of the subject, and on the conclusion of his remarks the President, and occasionally other masters, further elucidate the matter by questions. This continues till all necessary information is obtained, when the deputation retires. The business is then entered upon by the masters, and opinions are freely expressed.

Where difference exists, the majority rules; and it is to the credit of the masters, that for six-and-twenty years no one has attempted to break the rules or evade the decrees of the Association.

The deputation of workmen being recalled, the decision of the meeting is read, and always respectfully received, though it frequently happens that it is not in accordance with the wishes of the former. On three occasions only has the difference been so wide as to threaten trouble. The first was immediately after the formation of the Association, and, indeed, was its natural consequence. At that time, the men (inflamed by paid agents) looked upon their masters as tyrants, and a struggle ensued; the masters, firmly banded together, were of course victorious, and from the funds of the Association remuneration for loss by the strike was made to such masters as had suffered.

Having shown their strength, the masters from that time laboured to prove to their workmen that they would deal as fairly and liberally by them as possible. The other two occasions were each on petitions for 10 per cent. advance in wages, which were refused. The President, however, has power to call special meetings, and, after waiting for a sufficient period to elapse to show the masters were not acting on compulsion, he summoned the Association to meet and re-consider their decision. In both cases there appeared sufficient grounds to warrant them in reversing their course; the petitions were granted, and peace has been preserved. Twenty-six years have elapsed, with harmony betwixt masters and men, the former enjoying the confidence and respect of the latter; and all this has been effected without at any time having to give higher wages than those the men were justly entitled to.

So long as human nature exists there will always be difference of opinion amongst masters as to the remuneration properly due to workmen; and there will be workmen who chafe and become irascible at not obtaining things on which they have set their heart. And thus it is, that when the masters and workmen act isolatedly, and only on their own

local knowledge and wishes, obstinacy and anger too frequently precipitate harsh measures. It is a very different thing when each master must appear and prove his opinions by good evidence, before a board of masters determined to do justice to both employers and employed; and no deputation of workmen can put forward impracticable or manifestly unjust claims, because they have to discuss and prove all that they assert.

It is this judicial character of the board, and its determination to act only on proof, tempered with leniency to the workmen, that has so long and so happily maintained peace in the carpet manufactories of the North of England.

ON

THE MANUFACTURE OF HATS.

BY

WILLIAM WILSON.

The manufacture of hats has long been carried on in Newcastle; the felt makers having been associated with the armourers and curriers as one of the guilds of the town in 1546. Felting is the process of making a fabric, or cloth, by the interlacing of the fibres of the wool or furs of various animals; however fine and straight these fibres appear, they are all furnished with spurs, or have irregularities of surface (as may be seen by the microscope), and have a tendency to interlace; when moistened with warm water, or steam, and rolled under moderate pressure, this tendency to interlace and work together, by a vermicular motion is increased, and may be continued until a strong fabric is produced. It is probable that this art was known at an early period, as the tendency of these materials must frequently have been observed; but there is no account of felt hats having been worn until the twelfth century, when they were in use by ecclesiastics. Early in the fifteenth century they were adopted by laymen.

According to the "Hatters' Union," they were first made in London, in 1510, where the Felt Makers' Company was incorporated in 1604—more than half a century after they had been incorporated in Newcastle; but although thus early established here, there are no records by which the character or extent of the manufacture can be traced. It is known that, from the commencement of the present century, it was limited to the supply of the local demand for a strong and not very fine hat; and that about thirty years ago, when the silk-napped hats superseded the beaver naps in public estimation, only one manufacturer—the late David Colling, of Gateshead—adapted his works to the requirements of the new fashion; and for some years afterwards no felt hats were made in this vicinity.

Perhaps in no trade has the combination of the workmen, to regulate the price of labour and method of working been longer in operation or more stringent than in this, and the result has been injurious to all engaged in it. The employers knew that if they ventured out of the routine method of manufacture, they would meet with opposition at every point; the intelligent workman who may have seen any suggested change to be an improvement, and wished to try it, has been prevented and kept down to the level of his fellows.

Thus, although several important improvements were attempted early in the present century, and patents obtained for them, the proprietors were unable to contend with these obstacles; and manufacturers in other countries, less restricted by their workmen, have adopted and followed them up to a useful result, and have been able thereby not only to compete with, but to supersede, us in some countries formerly supplied from England, and even at home, and in our own colonies, to some extent.

About six years ago, William Wilson and Co., who were then silk hat makers, began a manufactory of felts, and were the first in this kingdom successfully to introduce machinery for felting. Their workmen have found the change beneficial to their interests—their weekly earnings having increased, although the rate per dozen is lessened, and the character of their work has become easier and more agreeable, requiring more constant attention but less physical toil. Much of their opposition to machinery has consequently passed away, but enough yet lingers to retard further improvements.

To show more clearly the nature of the improved method adopted by them, it may be well, in the first place, to give a short description of the old mode of manufacture by hand labour.

The materials, whether wool or fur, or a mixture of these, was placed on an open hurdle, when the workman, taking a bow about seven feet long, struck the catgut stretched between from end to end with a stick, so as to cause it to strike the material on the hurdle and throw it in fine loose particles on to the table; when half the quantity for one hat was thus spread, it was pressed under a piece of leather until somewhat consolidated, and the second half being formed in like manner it was laid on the first; a piece of tissue paper, of triangular shape, being between them to prevent the two portions uniting, except at the edges, where they were folded and pressed together until they united and formed what is termed a "bat" of a conical shape.

This "bat" required hardening by a continuance of the rolling in cloth, with an occasional application of steam to prepare it for the rougher

process of felting. This operation is performed at what is termed a planking battery, usually made for six or eight men to work at. It consists of a leaden vessel, or "kettle," filled with hot water containing a little vitriol, and surrounded by six or eight planks, each about two feet deep, and sloping to the kettle.

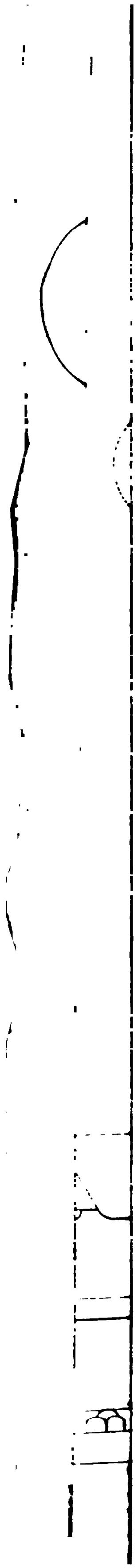
The workman dips his hat in the kettle from time to time and rolls it on the sloping plank in various directions, sometimes under a roller, at others in a cloth or with his hands, repeating this until the fibres have worked together into a firm body, or in other words become sufficiently felted.

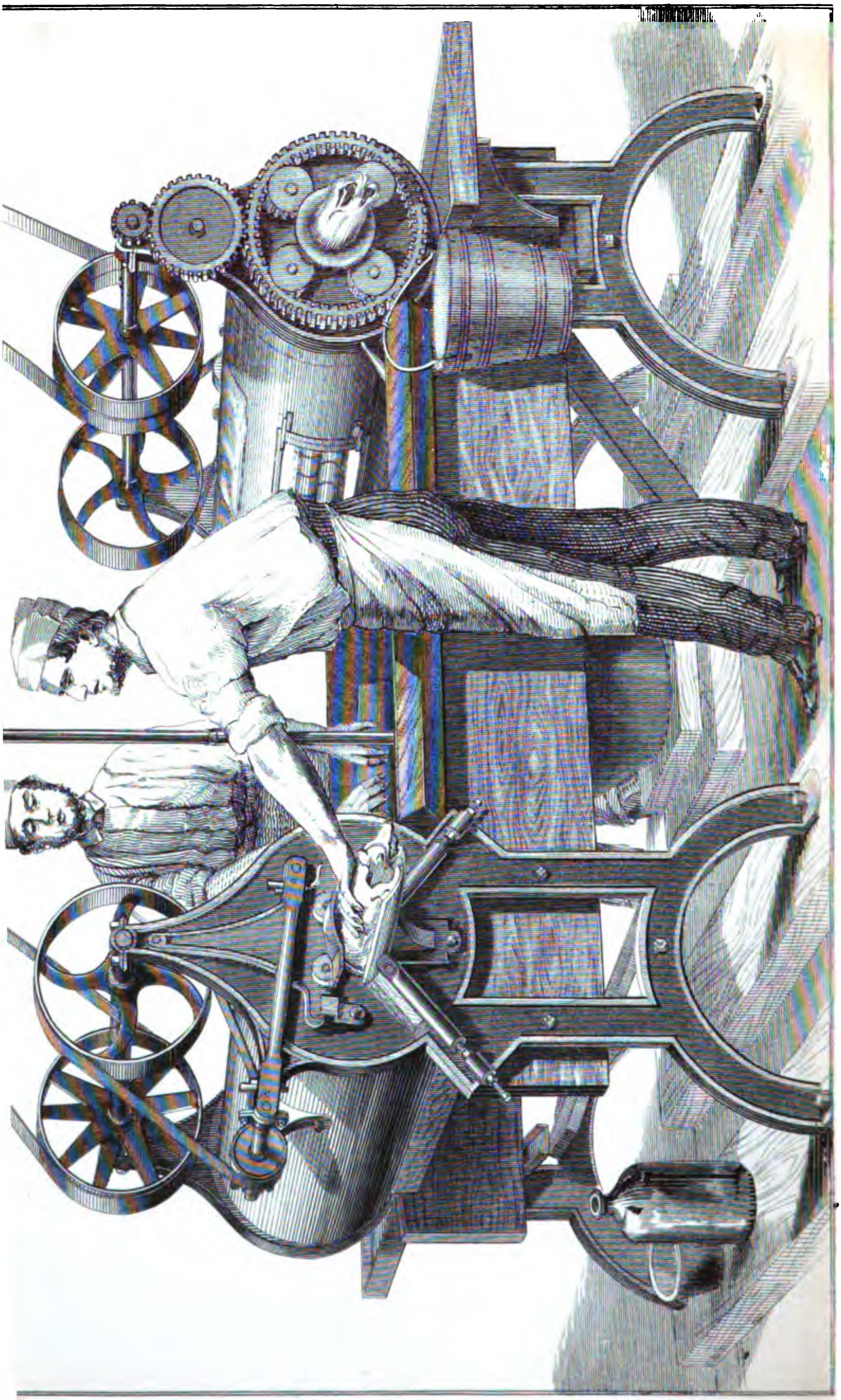
It has been found needful to adopt two distinct mechanical processes for making the bodies of wool and fur hats; the former, even the short lambs-wool usually employed readily forming a sliver, while fur is too short and straight to do so, and must be operated with in a manner more analagous to the "bowing" already described.

We will first describe the process of wool hat felting. See illustration.

The material, after being cleansed and carded in the manner usual in other branches of the woollen trade, is passed through a second carding engine in two portions, with a space of three or four inches between each, and as the sliver leaves the doffer it is guided on to the double cones or hat moulds, and as these revolve is wound round them.

This machine (see illustration) consists of two upright moveable frames or carriages, connected together by a shaft running between them, each frame or carriage bearing two pairs of cones rotated by bevil wheels, connected with bevil wheels on the before named shaft. Upon these cones are placed the conical hat moulds, which revolve by friction of contact with them, and round which the wool is wound as before named. In the centre of the shaft, between the carriages, is a right and left hand screw, the threads of which cross and unite so as to form a continuous groove, so that when the tongue or pin which runs therein comes to the end of one thread it turns on its pivot and runs back on the other, thus communicating an uniform reciprocating motion to the two carriages; the result of which is a continual crossing and recrossing of the wool as it is wound round the hat moulds; if it were not for this action the felted hat bodies would only yield in one direction, and could not be stretched into the required shapes; but as it is also needful to form the brim and band of the hat thicker and stronger than the upper part of the crown, this reciprocating motion of the carriages is stopped for a time by the following arrangement, so that the wool is then simply wound round the centre of the moulds.





At a right angle from the centre of the screw on the shaft is a slide, to which is attached a fulcrum with a hole through which a lever works; parallel with the shaft is a rod attached both to the lever and the carriages; parallel with the rod below the screw is a slide-rod supporting the tongue or pin, and carrying one end of the lever with it, while the other rests on the fulcrum. Another lever works on a pivot with its end extending over a ratchet wheel with pins on its outer edge, while the other end is connected with the slide at the fulcrum, so that as the ratchet wheel moves, the slide also moves, and carries on the fulcrum, thus shortening the action of the lever and the rod until the fulcrum comes under the pivot which connects them, when the rod ceases its reciprocating motion and the carriages also, until the pins in the ratchet wheel pass the end of the the lever, when it is released, and the reciprocating motion resumed.

By means of the ratchet wheel a bell is rung, when the required weight of wool is wound on the blocks; it is then divided in the centre by the attendant, and forms two "bats," which, each with an inlayer are then folded in cloths and placed on a perforated iron plate, through which steam passes. When sufficiently moistened and heated they are placed between two boards, to which a jigger action is given; by this means they are sufficiently hardened to bear the heavier operation of the planking or felting machine. See illustration.

This machine is worked by two men who have a "kettle" of hot water and acid (as in hand felting) between them, each also with a bench in front sloping down to it, and at each side a hollow cylinder, in which are four corrugated wooden rollers supported in bearings at each end, with a space between them, through which the hat bodies are to pass rolled up in cloths.

The corrugated rollers are not placed parallel with each other but obliquely, so that the axis of one, if continued, would cross the axis of any other. By this means, both a rotatory and a longitudinal motion is given to the roll of hat bodies between them; they are put into the machine at his right hand by each workman, and received from his fellow-workman at his left. The journals of two of the upper rollers in each set do not work in fixed bearings but in a frame with a horizontal sliding motion, by means of which a to-and-fro or rubbing action is given to the roll of hats; the journals of the two below them have a little space downwards in which they work against india-rubber springs, and are thus prevented receiving the damage that would result from an unyielding pressure. The motion is communicated to the machine by a pully on a shaft running above the cylinders, and furnished at one end with a bevil wheel working in con-

nection with others attached to the journals of the rollers—the workmen, as they receive the rolls of hats passing through the cylinders, open them out to dip in the kettle, and refold free from creases likely to form lumps. This operation is continued until the bodies are sufficiently felted.

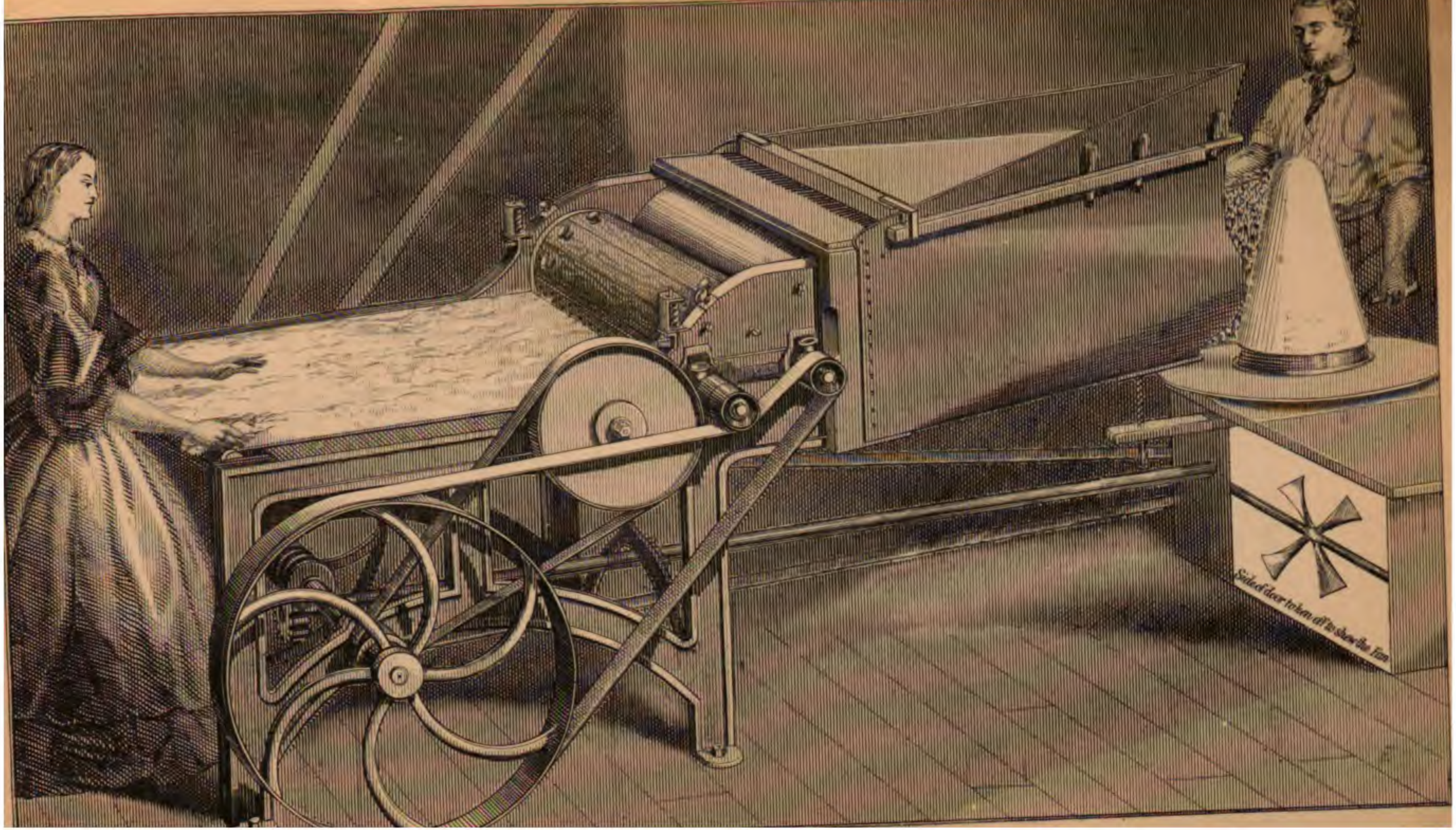
When the material employed is fur, there is frequently a variety of sorts which require to be thoroughly mixed, and the lumps and coarse hair thrown out; this is done in a machine called a "picker," consisting of a series of boxes (from six to twelve) connected together, and each furnished with a roller armed with fine wire teeth, which, moving at great velocity, catch the fur as it enters the box, and throw it upward and forward on to the travelling apron, which takes it on to the next, and so on to the end, when it falls into the receiver—the impurities having passed through a grating in its transit. For the finest hats it is often needful to make a greater separation of the coarser fibres than can be obtained by this process, and the fur is therefore brought under the operation of a fan making 2,500 revolutions a minute, which blows it along a passage seventy or eighty feet into a chamber about one-third of that length, where it is deposited, the fairest and lightest fibres being carried to the extreme end, and the coarser and heavier falling nearer.

To form the "bat," the fur is next taken to the forming machine. (See illustration.) Sufficient for one hat is spread on the feed-apron by the girl in attendance, and carried on between two rollers, when it is caught by a rapidly-rotating brush thrown through a trunk, and falls in a thin film on to a perforated copper cone, which, placed on a revolving table, successively presents every side to the mouth of the trunk; below the table a fan, making 3,500 rotations per minute, draws the air from the interior of the cone, so that the light fibres of the fur are held in position by the pressure of the air; covered with a cloth and a second cone they are immersed in warm water and then removed from the cone and subjected to slight pressure and rolling to harden them sufficiently for the felting process which is performed by hand labour, as before described.

The hat bodies, both of wool and fur, are next stiffened and made waterproof by a solution of gums (of which shellac is the principal ingredient); they are afterwards dyed in a bath composed of suitable materials for the desired colour, and then "blocked" by softening in hot water, and being drawn over moulds into some resemblance to the shape they are intended to be worn. These processes are very important, but a detailed description would not interest the general reader, and we therefore pass on to the process termed "Finishing."

Formerly, the hat—after being "blocked" as last described—was put

MACHINE FOR FORMING FUR HAT BODIES.



into more exact shape by being steamed on to a block, and ironed closely to it until its surface became smooth and bright; this object being aided by the use of a plush or velvet cushion. Some sorts of hats are now fitted to the block in the same manner; but they are then, whilst on the block, attached to a lathe turning at a moderate speed, and a piece of fine sandpaper, lightly applied to the revolving hat, quickly removes all the irregularities of surface, when the application of the velvet cushion gives the required brightness in a much greater degree than unaided by the revolving lathe. Other sorts are softened by the heat of a gas stove, and then placed in a mould the desired form of the hat. An iron frame, with an india-rubber bag attached to it, is then made to descend on to it, when water is turned into the bag at a pressure of 350 lbs. to the square inch, so that it fills the interior of the hat, and, pressing it in every part to the mould, produces a smooth exterior surface, which is then finished off on the lathe as before described, and is ready for the "trimmer" who puts in the lining and binds the brim, the edges of which are afterwards curled and put into proper shape for use.

The manufacture of silk hats is much simpler, and requires but two classes of workmen. The body maker who receives the calico used for the foundation, steeps it in a waterproofing solution, of a somewhat similar character to that used in felt hat making, stretches it on frames to dry, then cuts it into proper proportions to fold round the hat block, to which he attaches it by hot ironing, attaching a stouter portion afterwards for the brim. The finisher draws over the body a "cover" of silk plush, irons it closely to its surface, which has had a thin coating of varnish to cause the plush to adhere more readily to it; by repeated hot ironing, and lureing with a plush and velvet cushion like those used for felts, he brings the silk plush to a smooth and bright surface and the body to a tighter and more elastic substance; the hat is then lined, the brim curled, and it is also ready for use.

It is estimated that from 500 to 600 dozens of hats and caps are weekly manufactured in Newcastle and Gateshead, employing, with those engaged in the preparation of furs for that purpose, at least 600 persons. The latter branch of business is carried on to a considerable extent; about two millions of hare and rabbit skins being collected annually, part of which are exported, and the fur of the remainder separated from the skin and prepared for the hat manufacturers of our own country.

ON THE

MANUFACTURE OF HEMP AND WIRE ROPES.

BY

GEORGE LUCKLEY.

ROPEMAKING is one of the primitive arts. The remote antiquity of "hanging" significantly suggests the still earlier invention of the rope, which has always been the agent in that simple method of accomplishing the fate of persons "not born to be drowned." The demand for this purpose, however, never sustained the art, much less entitled it to honourable mention as a trade. Its importance, in this respect, has always depended upon shipping and mining, in the development of which it has been a chief agent. It was therefore natural, that at an early date, ropemaking should have had a seat among the industries of this locality, favoured in addition by the convenient and established intercourse of our ports with those of St. Petersburg, Riga, and Archangel, whence almost the whole raw materials of the manufacture were originally derived. Accordingly, ropemaking was one of the "nine mysteries" of old Newcastle; and the fraternity still constitutes one of the Incorporated Companies of Freemen in that town, where, for about forty years, it has had as one of its stewards, the well-known freeman, Mr. William Meikle. This sturdy roper has been upwards of half a century in one of the oldest roperies, and after witnessing the notable changes which, during that period, have overtaken his handicraft, he now stands its representative under its most recent development—that in which it exhibits, what may be literally termed, the power of an *iron* destiny.

As will be particularly mentioned hereafter, ropemaking, until about the beginning of the present century, was conducted after a very simple and unscientific fashion, apparently without improvement upon the practice of ages. In small ropeworks, the power was all manual, but horse-power was superadded in larger works. Excepting from the "tarring" of the yarn, which was done at intervals, according to requirement, the manufacture was performed throughout without smoke or other offensive

attendants. The most considerable and profitable part of the business was the making of cables for shipping. An ordinary collier brig, beside towline, warps, rigging, and running gear, was equipped with two hempen cables, each 120 fathoms long, and from 10 to 12 inches circumference, weighing 2½ to 3½ tons. The cables of ships of war were from 18 to 24 inches in circumference, weighing 8 to 15 tons.* In point of size, there is not in modern ropemaking anything to compare with these cables. Many large men-of-war's cables were made on the Tyne, at the Willington Ropery, about sixty years since. These cables could not be coiled into lifting coils nor weighed. The ropery was almost always contiguous to the river, or river communication, and commonly had rights of way over intervening property, for running the cables "on end" into craft which conveyed them to the ships. The weight was charged by a fixed rule, which had the reputation of giving a result more in favour of the roper than his customer. There were, at the same time, other usages in the trade, not adverse to the ropemaker, which disappeared upon the advance of competition and free-trade.

At that time a tolerably compact Association of Masters in Newcastle and Sunderland, enjoyed a common understanding and held together. The transactions and course of business, though important, were not rapid and manifold as now; and privileges and customs were legitimately maintained and admitted by our forefathers, which we, with the principles now permeating the commerce of the country, neither can, nor ought to hope for. The names associated in this district, with the trade at the beginning of this century and shortly afterwards, were:—*Newcastle*—Cramlington, Peacock, Rutherford, Smith, Chapman, Crawhall, Dodds, and Hodge. *Gateshead*—Hood, Errington, Winship, Haggie. *Sunderland*—Fothergill, Grimshaw, Hutton, Webster. *North Shields*—Linskill, Bradshaw. *South Shields*—Shadforth, Wawn. It will be observed that some of these names are still in the foremost ranks of the trade—Websters, Crawhalls, and Haggies, maintain their fathers' fame, while a Smith perpetuates his grandfather's. In the times above noticed, the master roper usually lived in a well circumstanced mansion, adjacent to

* A "first-rate" man-of-war's outfit of hemp rope weighed 78½ tons. At present, when the Legislature is enacting a law for the testing of chain cables, it is interesting to note that the cables of former days were the subject of State regulation. By 25 Geo. III., c. 56., the ropemaker was bound by penalties and forfeiture, to use only certain descriptions of hemp in making rope for shipping—to have his name upon the tally accompanying his goods, and to use the term "staple" or "inferior" upon each tally, to distinguish the rope made of the best or inferior material permitted by the Act.

the ropewalk and overlooking the river. His house, grounds, and ropery, had a rusticity not easily conceivable by those, who know only the present much changed aspects of the Tyne and Wear.

The process of the manufacture itself, underwent a course of change and improvement, commencing with the present century; but before describing this, it may be more convenient to relate a great change which overtook the trade from without—between the beginning and maturity of its internal improvements. In 1808, Mr. Slater, a Navy surgeon, obtained letters patent for making chain cables. This was not pursued further by him, probably (it has been said) from want of means. Immediately afterwards, however, Lieut. Samuel Brown, R.N., secured a patent for the same purpose; and he, along with Mr. Brunton and some other friends, fitted out an experimental ship (the "Penelope"). After her voyage, an account of the results of their tests and experience of the use of chains on board ship, was published, which induced the Admiralty to order that they should be tried in the Navy. In 1812, Mr. Brunton patented some improvements which obviated various defects,—the Admiralty then formally adopted chain cables for the Navy, and, in consequence of the war price of hemp ropes, the use of chain cables in a few years fully superseded that of hemp, and the most lucrative portion of the ropemaker's trade was annihilated. The blow was a serious one and inspired the gloomiest apprehensions. But patience and the expansion of commerce tided the trade over the emergency, and ultimately, not only did the chief ropeworks maintain themselves, but several new makers commenced operations. About this period and soon after, great developments took place in the uses of machinery and the steam engine, which gradually changed the character of the trade of the district generally, as well as revolutionised the interior of the primitive ropewalks. The ropemaker had to submit, not only to the appropriation of the best part of his business by the chainmaker, but the latter located himself, very frequently, near to the once pleasant ropewalks, and there plying his blacker art, made it a question of time only, how long the former should endure residence near the unwelcome sights and sounds produced by his opponent. For the most part, thanks to the rule for calculating the weights of the lamented hemp cables and other advantages of his primitive trade, he was able to shift himself to some more pleasant retreat, leaving his sons or successors to cope with the new events, and to inure themselves to the smoke and disfigurement which were settling down upon the river sides.

It was about 1816, that flat ropes were largely adopted for drawing coal. Their invention seems to have been due to Mr. John Carr, of Sheffield, in 1807. Round ropes from 4½ to 6 inches circumference, had previously been used. Besides their smoothness in working and other recommendations, flat ropes increased the amount of work, and became a very important branch of ropemaking. Although, in later times, they have been greatly superseded by wire flat ropes, they are still used in the coal districts of Scotland and Cumberland, and the supply to these districts, as well as to isolated collieries in other parts, is mainly drawn from Sunderland, Gateshead, and Newcastle.

We now retrace our steps to explain the internal changes which have taken place, as previously noticed. Before the commencement of the present century, the manufacturing process had remained without improvement in the memory of those then living. The spinning was all by hand in the way familiar to all, and still partially practised. The formation of the yarn into strands, and of the strands into ropes, was managed upon the whole length of the ropewalk, somewhat as follows:—The yarns in requisite number for the size of rope, were extended, supported at regular intervals upon "stake heads," the full required length; then, after being parted into the quota for each strand, they were twisted (from the ends) to the desired compact roundness; these strands (commonly three) being finally "closed" or twisted together into a rope. This method of forming strands was unscientific and very defective in large strands, because of the unevenness of the strands so formed; and because the yarns, being all the same length when gathered into the twist, they were, in proportion to the size of the strand, subject to great differences of tension when strained in the rope, according to their position upon the circumference or in the centre of the strand. All the improvements projected and effected, have had as their object the remedy of these defects, either separately from, or in conjunction with, such a plan as should at the same time dispense with the necessity for a long rope ground. The progress of these improvements will now be explained.

Excepting a patent in 1784, for a method of applying horse power, the first patent for improvements in ropemaking, was granted in 1792 to the Rev. E. Cartwright for a machine, which he named a "Cordelier." This machine was apparently a development of a model sent, ten or twelve years previously, to the Society of Arts Museum, by a Mr. Sylvester, but it was an essential improvement, and is important as forming the basis of all subsequent machines for making of ropes otherwise

than "on the ground," and is in fact perpetuated in the present most approved wire rope making machines. By the "Cordelier" three reels, (each holding the yarns for a strand, and by revolving on its own axis, forming the strand) were at same time carried round a common axis, thereby twisting the strands into a rope, while being "closed" and drawn away by suitable arrangements. From this time, improvements in ropemaking commanded an extraordinary amount of attention, and patents continued to be taken out in quick succession, all more or less embodying the same principles and differing only in details. The most notable patentees were:—Mr. Belfour, of Elsinore, Capt. Huddart, of London, and Mr. Wm. Chapman, of Newcastle, each introducing successive improvements from 1793 to 1807.

In this district, some important steps were taken in the introduction of the improvements, and the first in the kingdom to carry into operation his invention, was Mr. Richard Fothergill, of Sunderland, who secured, in April, 1793, a patent for machinery for preparing, spinning, and making hemp into rope without a rope ground. He constructed and fitted up, at Southwick on the Wear, a very large ropery upon this principle. Practically, however, this method was not successful until improved by subsequent inventions. The Messrs. Chapman, after spending "a fortune" in their attempt to sink Wallsend Pit, withdrew from it, and commenced ropemaking in the neighbourhood (at Willington), where they erected a very large and perfect ropery, bringing to the business very eminent abilities. Mr. Wm. Chapman himself, and subsequently, in conjunction with Mr. E. W. Chapman, effected progressive improvements in the manufacture, and brought both trade and credit to the neighbourhood, having secured large Government orders. They, simultaneously with Mr. Belfour and Capt. Huddart, before mentioned, effected improvements in the forming of the strands and in various other details, which still exist. It is not possible to distinguish how far each contributed to perfect the machinery now generally used. It may be sufficient to state, that from 1793 to 1805 Mr. Belfour took out three patents; Capt. Huddart four; Messrs. Chapman, four; that Mr. Grimshaw (succeeding Mr. Fothergill at Southwick) obtained a patent in August 1799, improving upon Mr. Fothergill's invention of 1793; that Messrs. Chapman obtained another patent in January 1802, for improvement in tarring yarn, and again in October 1807, one for improvement in making flat rope; that Mr. J. Crawhall, of Newcastle, procured a similar patent in 1832; and that in May 1833, Mr. William Norvell,

of Newcastle, took out a patent for a most efficient machine, which seems to comprise all that could be effected in an "*endless rope machine*,"* or one which makes strands and rope at one and the same time without a rope ground.

The effect of this protracted series of inventions was to bring, one by one, all the roperies into a scientific method of manufacture with machinery of one or the other of the above inventors' designs; and for the past twenty years, excepting in spinning machinery, scarce any alterations have been made. There is, still, considerable variety in the manufacture—hand-spinning is still preferred by some—which is perhaps not strange, since in Her Majesty's yard at Deptford, it has been resumed after a trial of machine spinning,—but, as a rule, the spinning is done by machinery. Mr. Lang, of Greenock, appears to deserve the credit of inventing the best machinery for this purpose up to 1832, but more recently, very excellent systems have been obtained from Leeds, and it is probably frôm defects in the earlier machinery, that handspinning has been preferred in the cases mentioned.

As regards the methods of forming strands and making ropes, there is still no uniformity of practice. By the improvements effected in the methods of making these on the ground, where the yarns, instead of being stretched in bulk as before described, are arranged in correct relation to each other, being passed singly through perforated plates and press blocks and tubes in such a manner that each yarn may share the strain of the rope however large,—the ropes are free from objection, and continue to be extensively made by those who have facilities for so doing. In such cases the "endless rope machines," or those which make ropes without the necessity of a rope ground, are also used and principally employed for such ropes as are too long to be made on the ground. Each system has its special recommendations in certain respects, so that at present in the roperies of this district, some spin all by hand,—some both by hand and machinery,—but the majority spin by machinery,—some makers who manufacture exclusively for shipping, produce their ropes upon the ground only,—some make both upon the ground and by "endless" machines,—but the largest quantity of rope is most probably made entirely by these machines.

* The tradition is that the essential parts of this machine were the invention of a Sunderland clock and watch maker, who died before he could perfect it; after which it was advanced and adopted by his patrons, Messrs. Grimshaw and Webster, but still with some defects, which Mr. Norvell succeeded in overcoming.

Prior to the Crimean war, Manilla hemp rope was used to a very trifling extent in this country, although largely employed by American and some other foreign shipping. Its high price was an obstacle to its use by the British shipowner. During the late war, the extreme dearness of Russian hemp caused Manilla hemp rope to be substituted in many cases, and its use was largely increased. This led to a greatly-increased production abroad, and reduced prices here, which process has gone on, until the cost of Manilla hemp rope has been considerably exceeded by that of Russian, even in times of peace, and the former has now a large preference. It is used principally for ships' running gear, but also, when tarred, for towlines, warps, &c. Its manufacture requires spinning machinery of the most modern and improved kind, and the Liverpool ropemakers were foremost in accommodating themselves to its proper manufacture, which they did with great success. The ropemakers of Sunderland and Newcastle have followed, and now there is a large "make" of Manilla cordage, on both the Tyne and Wear, equal in quality to that made in Liverpool. While the export of Russian hemp rope has almost, if not altogether, ceased from these ports, the Norwegians, Swedes, and Germans, are importing Manilla hemp rope from us instead of Russian hemp rope hitherto made by themselves, or imported from Russia.

WIRE ROPEMAKING.

Unless the wire suspenders of the bridge built at Geneva in 1823, may be regarded as ropes, the first attempt at wire ropemaking is claimed by the late Mr. Andrew Smith, a well-known inventor and mechanician, of London. He alleges that in 1828 or 1829, he made, for a particular experimental purpose, a piece of small wire rope, of fine wires twisted together; and although he, at the time, considered it an invention, it was laid aside until, as will be presently noticed, he brought the invention into a more definite shape.

In 1831, it is certain that ropes of wire began to be used in the silver mines of the Hartz Mountains. These ropes have been authentically described as not above 1½ inch diameter, composed of three strands, each containing five wires. They were used in substitution of of hempen flat-ropes, *four* times their weight,—usually lifting 1000 lbs.,—effecting a saving of power amounting to two horses out of six, and working two years, almost without perceptible wear, where a hempen rope was all but worn out in one year. After this, wire ropes became rapidly adopted throughout the mines of Hungary and Austria to the

exclusion of hempen ropes. Wire ropes were also introduced into the collieries of Prussia shortly after the year 1833, with highly satisfactory economic results,—the published statistics stated the durability of wire ropes in drawing coal, as two to three times greater than that of hempen ropes, and the cost per weight of coals lifted, as still more favourable to the former. In 1835, M. Albert published in Germany a particular description of the manufacture of the wire ropes used in the Hartz mines, which memoir was translated and published in this country, in the Mining Review, February, 1837, and was useful, both in drawing attention to the subject itself, and in indicating the various points requiring attention in the manufacture of such ropes.

Prior to these dates, however, the invention had not been forgotten in this country, for it has been proved that Mr. J. B. Wilson, in 1832, made for Haydock Colliery a wire rope which answered satisfactorily; and in January, 1835, Mr. A. Smith (already mentioned) obtained a patent for an invention of wire rope, intended principally for ships' standing rigging. In March, 1836, a further patent was granted to Mr. Smith, *in conjunction with Mr. J. Lionel Hood, of Newcastle-upon-Tyne*, and from this date Mr. Smith's plans were so practical, that the manufacture of wire rope was commenced at Great Grimsby, on a considerable scale, on his process. Collieries were supplied, ships and fire escapes fitted, and experiments and tests were reported. The Admiralty became so interested in the matter, that, in May of the following year, official tests of Mr. Smith's rope were made, and the results proved so satisfactory, that in 1838 its use was sanctioned, and shortly afterwards several of H.M. ships were supplied with the wire rope. The London and Blackwall Railway, at this time, was worked by stationary engines and Mr. Smith's wire ropes. In March, 1839, Mr. Smith obtained the last patent of which we have any notice; but up to this time, in this country, wire rope appears to have been still upon its trial, and not much used by the mining interest.

In 1840, Mr. Matthias Dunn, coalowner and viewer, of Newcastle, published in the Mining Journal a most favourable report of the advantages of wire ropes for colliery purposes; but although these were demonstrated, there seems to have been but little encouragement given to the new manufacture in the great mining districts. Probably the ropes made, up to this date, were not of so perfect and reliable a construction as quickly to command the confidence of those who, besides having to provide for the alteration of gearing, also felt the responsibility of risk to human life.

In 1840, Mr. R. S. Newall, of Dundee, and Mr. W. Kuper (founder of the business now carried on by Glass, Elliott, and Co.), appear, simultaneously, in possession of an improved method of making wire ropes. By mutual arrangement, a patent was taken out by the former on the 7th August, 1840. After making his machinery in Dundee, Mr. Newall chose the ancient seat of ropemaking for the carrying out of his manufacture, and fixed upon an eligible waterside site near Gateshead, where he erected a remarkably well-appointed manufactory. He soon produced ropes which fully satisfied all requirements, and proved the superiority of wire over hempen ropes for colliery uses, and their adaptation for work to which the latter were quite inapplicable. This was another turning point for the ropemaking of the Tyne and Wear, and no doubt, for some time, the ropemaker looked upon the new comer as a rival likely to deprive him of his trade to a greater extent than even the chainmaker had done. However, the progress of events was less rapid—the change more gradual—than had been anticipated. The prejudices of masters and men, the expense of alterations, the small inducement as regards first cost, all operated to make the adoption of wire ropes very gradual, even after their superiority was admitted; and the hemp ropemakers were thus prepared to turn to a friendly account that which at first had threatened to injure them. Messrs. Webster, of Sunderland, presently followed Mr. Newall into the field, at first in opposition to his patent, but ultimately by paying him a royalty; and a large business was afterwards driven upon the banks of the Tyne and Wear in the new manufacture. In fact, as a *successful trade,* wire ropemaking may fairly be said to have acquired its first name and fame in this locality. The other hemp ropemakers on the Tyne, whose colliery trade had much fallen off by the time Mr. Newall's patent approached its expiration, were then ready to take up the manufacture, and commenced to regain, as far as they could, their former customers. The reduction in price which ensued, and the stimulus which this gave to consumption, joined with that intelligent course of improvement and increased rate of production which have latterly characterised mining operations, soon caused the demand for wire rope to afford all the makers sufficient trade to replace that lost of hempen rope; while the expansion of the commerce of the district has so contributed to augment the demand for shipping purposes, that, probably, the production of *hemp* rope in this district is even now as great as it has ever been. All the manufactories which enjoyed a colliery trade have, without exception, now combined wire ropemaking with hempen; while *some,* whose trade was entirely with shipping, have also

done so. *All* who make wire rope supply hemp rope also, so that the two branches are now truly one trade—a *few* roperies only, not yet making wire ropes.

The process of wire ropemaking is of course based upon that of hemp. There have been considerable disputes concerning the *merits* of the earlier methods of manufacture, and the *originality* of that patented by Mr. Newall; but there is no dispute upon the merits of the *latter*, and the influence it has had upon the success of the trade. In the earliest uses of wire in the construction of bridges, the wires seem to have been formed into what may be termed little better than huge "skeins," bound at intervals by external wire lappings, so as to compact them and retain them in form, the loop ends of each "skein" affording the natural means of union for their connection. This simple formation yielded the full strength of the wire. The next step in the use of wires, for purposes analagous to rope, placed the wires parallel to each other, and by equal tension pressed them into what, in ropemaking, would be regarded as a simple strand. This was lapped spirally, end for end, closely and tightly with fine wire, upon which was wound (reversely to the lap of wire) a woollen lapping, over which was "served" tarred spunyarn; the latter process being precisely that of "parcelling" and "serving" ships' rigging now, and having for its object the protection of the rope, while the lapping of wire was for its form and stability. We find next a decided type of rope adopted, corresponding, in fact, with hempen rope made "on the ground"—the strands being throughout formed of a great number of wires twisted into a spiral. Then followed the method patented by Mr. Newall, and which now prevails; answering to the system of the hemp ropemaker's "endless rope machine," as the last mentioned does to his method "on the ground."

The distinctive features of this plan consist in the use of a core for each strand, and the avoidance of all twist to the wires. As a general rule, too, the number of strands is six, in distinction to *four*, and the number of wires in each strand *six*, in distinction to an indefinite number in the preceding method; but these general rules are not indispensable to the system. In "formed" wire ropes, as made prior to Mr. Newall's patent, a considerable twist was given to the wires in the process of making; and to modify this evil, many *soft or annealed* wires had to be used to make a strand. These ropes were, therefore, inferior in strength and endurance of friction: both most essential defects for mining uses. When made on the method previously described, the rope was too rigid

and non-elastic, and the "service" subject to rapid wear. None of these objections apply to the "laid" rope made on Mr. Newall's plan, which permits of varied modifications in the rope, and consequently is adapted for general purposes, and produces, as far as can be expected, "a rope that is a rope," with lightness, hardness, degrees of pliability, and perfectness of form. The general use of this method of manufacture, and of the rope made by it, is the best proof of its superiority.

A similar rope can be, and is, made by a very ingenious machine, different altogether in arrangement from Mr. Newall's. It is the invention of Mr. Archibald Smith (son of Mr. Andrew Smith, already mentioned at length in relation to the introduction of wire rope). This machine, instead of placing the bobbins of wire on a circle, and making them revolve round the axis of the machine, places them in horizontal line, seven deep, in the centre of an extended frame which revolves round them, and carrying their separate wires and core to the laying plate, then closes them into the strand (or, as the case may be, the strands into a rope). The advantage of this machine is, that it admits of a speed quite impracticable where the bobbins revolve with the machine. Mr. Smith's machine can be driven to three or even four times the speed of the ordinary machines, and from ten to twelve hundred yards of light strand are turned off by it in an hour. It is therefore a favourite for strand-making for signal line, and telegraph cable-covering strand.

Mr. Newall's original drawing, and the beautiful working model he exhibits, show a "compound" machine, or one which both makes the strands and rope by the same operation. In practice, however, this has been discarded, as the advantages of accomplishing both operations in one, are more than sacrificed by its disadvantages. In spinning the strands distinctly, the jointing of the wires, and replenishing of the bobbins, are very easy, and delay only the few other bobbins for that strand—while the closing of the rope is not subject to any delay whatever from this cause. In the compound machine, which is exceedingly complex, the jointing and replenishing are not only less readily done, but the delays stop on every occasion a great number of bobbins (say 42), and likewise suspend the progress of the "closing."

Wire flat ropes were made first, about 1836, of a number of simple, slightly-twisted strands, composed of small wires, these strands being embraced and formed into a band by what may be described as a weft of strong yarns. This weft soon failed at the edges from wear, and this description of rope almost immediately gave place to another which

obtains to the present time. In this, *ropes* are introduced in place of strands, thus admitting of stitching, as the means of their union, and this stitching is performed after the method for hempen flat ropes, but requiring to be done by hand and with greater care. The ropes are laid flat and held closely parallel in a frame, are penetrated from side to side with a strong needle opening between the strands of every rope diagonally for the passage of a lacing of soft wires, which are then drawn tight, and the needle withdrawn, the strands closing upon the stitch.

The results of the use of wire rope for colliery purposes are important, as these ropes are applied where hempen ropes could not be used. In some situations the friction precluded the use of the latter;* while their weight and elasticity limited the depths for their employment in drawing coal, as a hemp flat rope of great working size soon becomes too heavy for its own strength. Independent of restricting, or being disadvantageous in the working of deep pits, the extra weight of hempen ropes was always a pecuniary loss, involving, to that extent, an increase of engine power, or a diminution in the weight of the mining produce lifted. A hempen flat rope of 150 fathoms itself weighed about three-fifths its working load, while a wire flat rope weighs only about one-third its working load. This advantage is, moreover, accompanied by a saving in first cost of above one-half, besides greater durability. The *rate* of working also could not have attained its present proportions with hempen ropes. Now we hear of 54 cwts. of coal, on an average, each lift coming to bank in six iron tubs and a heavy cage—probably having a total weight (without the rope itself) of five or six tons, amounting in an ordinary day of 12 hours, to 1,200 tons lifted; or 2,000 tons working throughout the 24 hours. Wire flat ropes six tons weight are used, while a hemp rope, of equivalent strength, could not be worked.

The adoption of *steel*, instead of iron, wire was expected to carry these advantages still further, the improved steel wire for ropemaking being supposed to be equal in strength with charcoal-iron wire of one-half greater weight; and a considerable mining use of steel wire ropes has been made; but the elements of cost and reliance still favour the use of charcoal-iron wire ropes.

As regards shipping, the adoption of wire ropes has been much more

* At one period the average duration of a pair of hemp round ropes in one of the Wallsend pits, where the shaft was very destructive of the ropes, was six weeks, and during the war a single pair of these ropes cost £120, owing to the high price of hemp.

limited than in mining, particularly in this district where the prejudices of shipowners have been long in yielding. In the case of steamers and iron ships, wire rigging is almost invariably used; but in wooden vessels, it is only coming into favour (excepting for particular "stays"). Its use is, however, now very rapidly extending, and there is an increasing export to the shipping and shipbuilding ports abroad.

It is not only in mining and shipping that wire rope has become of prominent service. It has brought the ropemaker into connection with other undertakings of which no one previously could have thought. Its essential connection with the art of the electrician, especially in his surprising submarine undertakings, makes it of world-wide consequence. This district, however, cannot assume more than, what may be termed, a personal connection with this application, Mr. Newall having established a factory at Birkenhead for that department of his business; with Messrs. Glass, Elliott and Co., the other eminent firm engaged in the making of electric cables, we have also a personal link—Mr. Elliott being by birth, long residence, and mining relationship, connected with this locality.

In steam cultivation, also, the ropemaker is introduced into *fields* strange to his original art. Here the use of wire rope is essential; but for this purpose, specially adapted steel wire is exclusively used (a pair of ropes costing about £55), and a large consumption goes on from this quarter and elsewhere, principally for Lincolnshire and adjacent counties.

Besides these applications, we may allude to the new uses which have been found for ropes and cordage of wire, in bridge building, fencing (at home, and especially in India), signal strands, pit shaft guides (or conductors for the cage), lightning conductors, window-sash line, picture-hanging cord, clothes line, and many domestic uses, where its cheapness, lightness, strength, and durability are of peculiar advantage.

This branch of local industry, therefore, although remote in origin, and subject to notable innovations, has not waned; but though, as compared with former days, it is now much overtopped by the modern and more rapid development of other manufactures which surround it, it still shows every token of vitality. In its nature, being but accessory, it will probably share the fortunes of its neighbours, the mining and shipping interests. It has acquired, however, here a general character such as attaches to it in no other locality, and both at home and abroad this neighbourhood is now recognised as the centre of wire ropemaking. There is no other place which has this specialty; and the probability is, that the chief part of the mining demands throughout the kingdom will

continue to be drawn from the district, while there is every probability that an increasing export trade will be developed.

It is not easy to ascertain the present statistics, but the following are probably sufficiently approximate.

TYNE, WEAR, TEES, AND BLYTH.

	Tons.	Value.
Hempen Rope manufactured annually	8500	... £160,000
Wire Rope do. do.	4500	... 170,000
Total	8000	£330,000

APPENDICES.

No. I.—ABSTRACT OF TWO PAPERS BY J. EVANS AND T. WRIGLEY, Esqrs.

The views expressed in the previous report are, however, seriously doubted by many, and the following abstract—from two papers read at the meeting of the National Association for the Promotion of Social Science at Edinburgh, Oct. 9th, 1863, by John Evans, F.S.A., F.G.S., and Thomas Wrigley, Esqrs.; the former on The Manner in which the British Paper Manufacturer is affected by Foreign Legislation, and the latter on The Paper Trade, its Position, as affected by British Legislation, contrasted with the true Principles of Free Trade—will put the reader in possession of the principal facts of the case.

"The supply of the material for the manufacture produced in this country is considerably less than the demand, and this deficiency has, of course, to be supplied by importation. The quantity of rags imported into this country being, on the average, about 20,000 tons per year. The same state of things exists in America, the importations into that country, from England and elsewhere, being about 30,000 tons per year. In other countries, however, the reverse is the case. The supply of rags considerably exceeds the demand, and under these circumstances the price of rags in England is regulated, on the one hand, by the price for which they can be imported from abroad, and on the other, by the price at which they can be sold in the United States.

"In almost every country on the Continent of Europe, a heavy duty is levied on the exportation of rags, and, consequently, French, Belgian, German, and Dutch paper-makers obtain their rags at a considerably less price than the British manufacturer.

"These duties vary from £5 to £9 per ton; and as it takes 30 to 40 cwts. of rags for every ton of paper, the effect of these duties is precisely the same as that of a bounty on the exportation of the paper made from them, to the extent of £7 to £14 per ton, or say from 15 to 30 per cent. on the value of the paper, giving the Continental an advantage to this extent over the British manufacturer. Up to the period when the Treaty of Commerce with France came into operation, in 1860, there had been, in consideration of the effect of these import duties on rags, a differential duty of 1d. per lb. in excess of the Excise duty levied on foreign paper coming to this country; so that, practically, the Foreign and British manufacturer were on equal terms so far as the British market was concerned, though the former still had an advantage in exporting paper to our colonies and elsewhere.

"This fair and equitable arrangement was abolished in 1860, and foreign paper was admitted free of duty, notwithstanding the retention of the export duty on rags by foreign governments. The effect of this has been, that whilst the price of rags

in England not only maintain but advance their price, that of paper has been very much reduced, in consequence of the large importations from France and Belgium.

"The imports of paper in 1859 were under 1,000,000 lbs.; in 1862, above 20,000,000 lbs.; and the exports of paper from France to this country in the first six months of 1863, exceeded those of the whole of the year 1862. There are those who defend the present state of things as the legitimate result of the adoption of the doctrines of Free Trade. To this it is sufficient to reply, that Free Trade does not mean a bounty to the foreigner, for that is the effect of the present arrangement, and it makes no difference to the British manufacturer whether this is paid by the Government abroad or at home—the effect is the same; and were the rag duties abolished, and the price of rags the same in this country as elsewhere, the British manufacturer could make them into paper as cheap or cheaper than his Continental rivals, so that consumers of paper and the public are not benefitted but injured by the present arrangement, and the very object of Free Trade is not attained.

"It is often suggested that the better collection of rags in England, and the adoption of substitutes for rags, such as straw, Esparto, &c., will in time remedy this state of things, by affording an increased supply of paper-making material. Unfortunately, it is not the *quantity* of rags, but their *price*, that affects the manufacturer; and not even the absolute price, but the *relative* price between rags in this country and on the Continent.

"Foreign paper-makers are quite as ready in adopting substitutes for rags as Englishmen, and any additional supply of rags is bought by exporters to America, who buy in the English market the moment the price falls below that of foreign rags, plus the duty; so that, as it was argued, and rightly, during the agitation for the repeal of the import duties on corn, that the duty enhanced the price of the whole of the corn produced in this country, as well as that imported, so it is evident that these export duties on rags abroad enhance the price of all rags in England, and the demand for export to America keeps up the price of rags here above that on the Continent, to the full extent of the duty.

"The result of this state of things will be the gradual extension of the paper trade on the Continent, and its partial extinction in this country by the unfair and unjust legislation of 1860, *unless the import duty is temporarily reimposed, and its abolition made conditional on the abolition of the rag duties abroad.*"

The foregoing is a short abstract of these able and instructive papers. Since October, the Government has concluded a treaty of commerce with the Kingdom of Italy, in which the export duty on rags is doubled—thus still further damaging the position of the British manufacturer.

No. II.—NOTE ON THE MANUFACTURE OF FRENCH ASSIGNATS.

The following is an extract from "The Political Life of Sir Robert Peel," by Thomas Doubleday, Esq.:—

"The author having, in a former work ("The Financial History of England,")

erroneously stated that the paper used for the forgery of the assignats was made at Langley Mill, in the county of Durham (a mistake probably arising from the proprietor of the mill, where the paper was actually manufactured, having the same name as the proprietor of Langley Mill), deems this a proper opportunity for clearing up this undoubted historical fact, which he is now enabled to do. The circumstances which led to this result are these :—Being, during the spring of 1852, in the course of a fishing expedition, at the house of Christopher Colbeck, Esq., of Walwick Grange, on the North Tyne, and the fabrication of the French assignats having been accidentally alluded to, Mr. Colbeck assured me that the paper for that purpose was unquestionably made at Haughton paper-mill, on the North Tyne, on the estate of a neighbour of his own, William Smith, Esq., of Haughton Castle. Mr. Colbeck further kindly proposed to introduce me to the acquaintance of Mr. Smith, who would, he was sure, readily afford me full proof of the facts of this curious transaction. To this proposal I, of course, readily acceded, and towards the end of April, having again become a visitor at Walwick Grange, I found that Mr. Colbeck had arranged with Mr. Smith that we should spend a day at Haughton Castle, which we accordingly did. From the kindness of Mr. Smith, I obtained evidence of the whole circumstances, which precludes all further doubt upon the subject. The substance of Mr. Smith's narrative was this :—Towards the end of the American War, and during his father's lifetime, one of the farms of the estate of Haughton Castle was held by a farmer named Magnay, a married man, with more than one son. In due time, one of the young Magnays found his way to London in search of fortune ; and being probably favoured by the partners in the paper-mill, of whom the then owner of the estate was one, he became a wholesale stationer, and being steady, clever, and active, he soon rose to eminence as a stationer, and became an alderman of the city of London.

"From Alderman Magnay, some time after the declaration of war with France in 1793, came the order for the paper to be used in the fabrication of assignats. Having passed some years of his earlier life on this secluded spot, he must have known its fitness for a purpose where publicity was not desirable ; and hence the transmission of the order to a concern in which his father's landlord was a partner. For a transaction of secrecy no situation can exceed that of Haughton paper-mill, which is placed beneath the eminence on which this beautiful old border fortress stands, far distant from any other habitation, with no town nearer than Hexham, which is many miles distant, and surrounded by country where all the wildness of the border still exists to a great extent. That the purpose for which the paper was wanted was fully understood by the partners, Mr. Smith assured me. Indeed, the mould in which the paper was made, and which he showed us, leaves little room for doubt. It is calculated to manufacture a small oblong sheet, each of which made four assignats. Mr. Smith obligingly gave me some paper, made from it, to exhibit the water-marks, which prove the purpose. The date of 1790 appears on each compartment, and at the left end of each note is a sort of ornamental flourish, resembling those we sometimes see imprinted on bank notes. Mr. Smith's belief is, that the plates were struck off in London, although he distinctly remembers seeing several of the fabricated assignats (probably sent down as curiosities by Alderman Magnay) in his late father's possession ; and I have been further assured by Mr. John Bell,

land-surveyor, of Newcastle, who knew the late Mr. Smith, that he obtained from that gentleman more than one of the fictitious assignats, which he afterwards parted with at the solicitation of various friends. There cannot, therefore, remain any reasonable doubt as to this curious matter of history. Lukyn, the defendant in the action, was some obscure stationer, probably, employed by Mr. Magnay to obtain the plates, strike off the fictitious assignats, and manage the details of the affair."

ON THE

TANNING TRADE OF NEWCASTLE & GATESHEAD.

BY

THE LATE T. C. ANGUS.

ON THE

TANNING TRADE OF NEWCASTLE & GATESHEAD.

THE following is the most correct account I have been able to obtain respecting the Tanning Trade of Newcastle and Gateshead. Some of the persons engaged in the trade have an objection to supply information; but I believe the figures appended to the paper will pretty nearly represent the actual transactions in this branch of local trade.

At present we have only nine tanyards in operation in Newcastle, four of some magnitude, the remainder small ones. Thirty years ago, Newcastle was styled the leather metropolis of the north, and buyers came from all parts to purchase. Public fairs were held twice a year, and supplies sent in from all parts of the country by small tanners, who generally had a few pits in a piece of open ground, and about two or three acres of grass land to fill up vacant time, and on these they managed to get wealthy.*

The character of the tanning trade in Newcastle has considerably changed of late years. The goods most in favour formerly were dry Russian hides, imported into this port at a cost of from 7½d. to 8d. per pound. These were anxiously bought up by the tanners, and the price realized left them 25 per cent. for manufacture. This trade continued for some time, but Yorkshire enterprize discovered it, and at Leeds most extensive yards, fitted with every known improvement, were laid down. In this way the Leeds tanners succeeded in securing the trade almost exclusively to themselves; one tanner there alone producing as many tanned hides in one week as all the Newcastle tanners could in one month. Thus, gradually, by improvements and perseverance, they, to a great extent, obtained the bulk of this portion of the trade. Owing to the great demand for these Russian hides, and the home consumption

* A singular mode of remitting the proceeds of his leather at Newcastle fair, in 1810, was adopted by a Lancashireman. The amount (£200) was put into the old sheets which had covered his leather. He dare not carry it, nor dare he trust any banker with its remittance, but it arrived safe by carriers' wagons after several days' journey. We are in advance of this in these days.

increasing at the same time, prices in Russia ran up to 12d. and 14d. per pound, and thus nearly cut off the importation. At these prices the hides yet continue, and they are now scarcely worth the tanner's notice. The substitute has been East India hides; but here again, the Leeds men have taken the lead, surpassing us in the rapidity of manufacture and cheapness of production, and obtaining the greatest portion of the trade to themselves. Newcastle can boast of being at the head of the trade in the manufacture of seal skins, calf skins, and sheep skins; and it is gratifying to find that although one branch of our trade has changed hands, another, and one perhaps as profitable, has come in its place. A consumption of 163,000 seal skins, 62,124 calf skins, and 46,452 sheep skins, in one year, shows that the spirit of leather manufacture has not yet left Newcastle. In the production of this kind of goods I believe our tanners cannot be excelled.

The products of leather in Newcastle are a mere item in the consumption. We have to resort to Bristol, London, Liverpool, &c., &c., for our great supplies. In these places so much attention has been devoted to produce work by the use of other tanning material than oak bark as to give them a great advantage over Newcastle, enabling them to supply goods thoroughly in accordance with the requirements of this north country trade.

On the whole, I think the tanning trade of Newcastle is in a healthy condition, but few improvements or efforts to increase it have of late been made. One remarkable circumstance should be noted in conclusion. A few years ago we used to import a large portion of raw hides from Denmark, Holland, and Germany; now the tables have turned, and we are weekly sending there raw hides from Ireland, for which they will give a higher price than we can afford for manufacture here. The Hollanders and Norwegians, who used to wear wooden soles, will now have leather boots and shoes, which greatly increases our export of leather.

The following are the statistics of the tanning trade in Newcastle-upon-Tyne and Gateshead, for the year 1862:—

QUANTITIES AND VALUE OF TANNING MATERIALS.

	Tons.	£	s.	d.
Bark	1780	9,753	0	0
Valonia	154	2,202	0	0
Gambier	50½	980	0	0
Carried forward ...	1984½	12,935	0	0

	Tons.		£	s.	d.			
Brought forward ...	1984½	......	12,935	0	0			
Divi divi	55	......	772	0	0			
Shumac	314	......	4,315	0	0			
Lime and pigeon dung... ...	—	......	324	0	0			
Oils (cod and linseed)	118	......	5,310	0	0			
Tallow	—	......	100	0	0			
Dyes	—	......	800	0	0			
Striping materials	—	......	100	0	0			
Eggs	—	......	600	0	0			
Alum and soda	—	......	200	0	0			
Dogs' manure	—	......	280	0	0			
						£25,736	0	0

NUMBER, WEIGHT, AND VALUE OF RAW HIDES AND SKINS.

	No.	Tons.	£	s.	d.			
Butcher hides ...	38,020	718	24,908	0	0			
Calf skins	62,124	84	9,320	0	0			
Sheep skins	46,452	—	2,322	0	0			
Seal skins	163,000	873	40,750	0	0			
						£77,300	0	0
						£103,036	0	0

VALUE OF THE ABOVE WHEN MANUFACTURED.

	£	s.	d.			
Butcher hides	£47,500	0	0			
Calf skins	16,378	0	0			
Sheep skins	3,871	0	0			
Seal skins	67,915	0	0			
				£135,659	0	0

ON

THE CONSTRUCTION OF IRON SHIPS,

AND

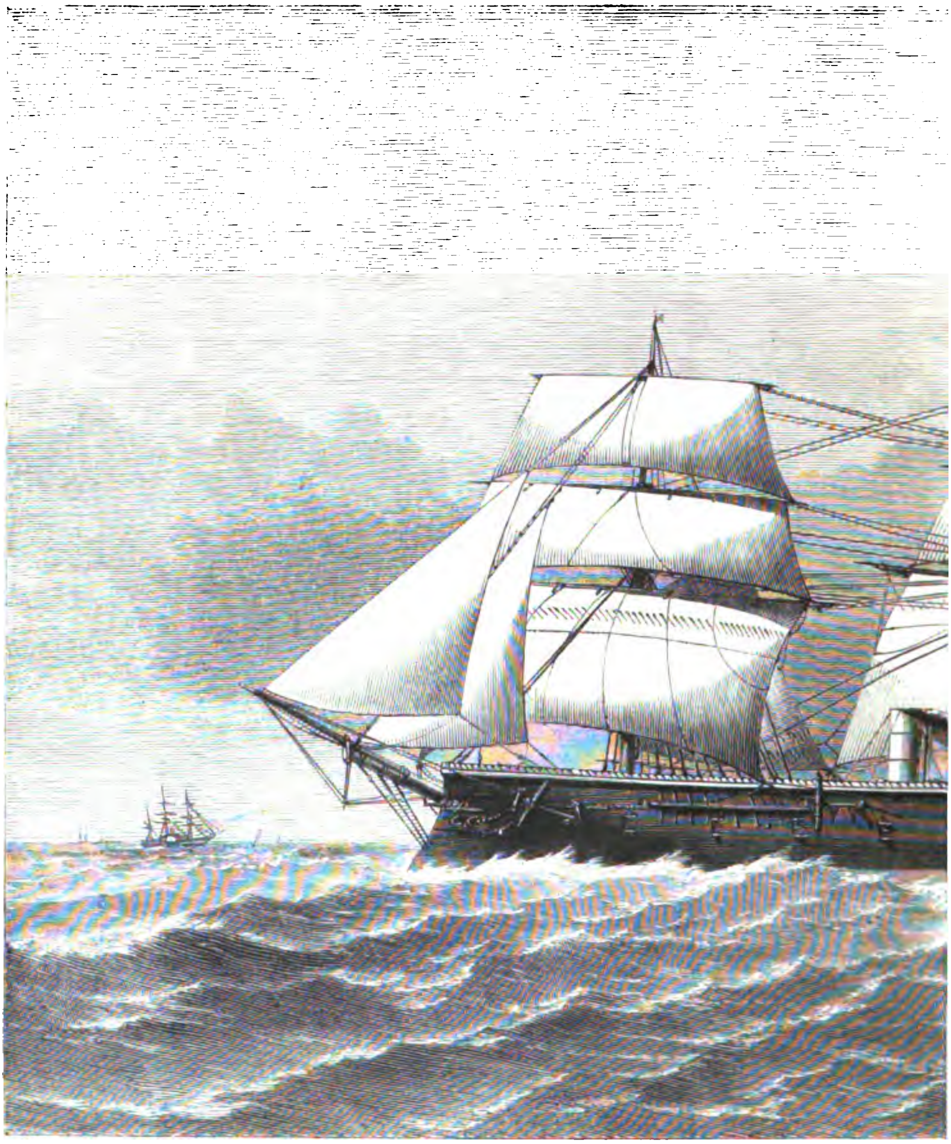
THE PROGRESS OF IRON SHIPBUILDING,

ON

THE TYNE, THE WEAR, AND THE TEES.

BY

CHARLES M. PALMER.



HER MAJESTY'S IRON-CASED

Built by Messrs. Palmer Brot

SCREW FRIGATE "DEFENCE."

:thers & Co., Newcastle-on-Tyne.

ON

THE CONSTRUCTION OF IRON SHIPS, &c.

THE paper which I have the honour to bring under your notice is limited to a brief explanation of the general principle upon which iron ships are constructed, and a short statement respecting the progress of Iron Shipbuilding on the Tyne, Wear, and Tees.

The art of constructing ships dates from remote antiquity, and we find in history, sacred and profane, many particulars of the ships in use in ancient times. As civilization advanced, and the science of navigation became better understood, ships increased in size, strength, capacity, and speed. Year after year brought its improvements, century after century its changes, until the art of shipbuilding in wood approached perfection, and the rude coracles and row galleys of our forefathers had given place to the clipper ship, with its fine lines, tapering masts, and flowing canvas—the merchantman driven by steam at a high speed across the ocean, and the three-decked, steam-propelled man-of-war. Then a demand arose for vessels of a still higher character—merchantmen possessing still greater speed, men-of-war sufficiently powerful to resist the destructive shot and shell which the genius of men, like our friend and townsman, the President of the Association, was inventing. With wood as the material to be employed, this demand could not be met; but human skill was equal to the emergency. The important discovery was made that "ships built of iron float lighter, strength for strength, than ships built of wood;" and, although for many years the prejudices of some men, and the interests of others, prevented the general adoption of the principle, it eventually triumphed, and now iron is rapidly superseding wood as a material of which ships are constructed.

The principal advantages that are claimed for ships of iron, as compared with vessels of timber, are briefly these.

In vessels of 1000 tons the iron ship will weigh 35 per cent. less than

the timber vessel, the displacement of water being the same. The iron ship will, therefore, carry more weight, and as the sides are only about one-half of the thickness, there will, consequently, be more space for cargo. The additional strength obtainable, too, allows iron ships to be built much longer and with finer lines, thus ensuring higher sailing or steaming qualities, with greater carrying power, and therefore, greater commercial results. In wooden vessels repairs of ruinous extent are frequently required, while the repairs in iron ships are generally of a lighter character, and are only needed at long intervals. An iron ship is not liable to strain in a heavy sea, whereas the straining of a timber vessel often damages a valuable cargo. The bilges of an iron ship can be kept clean and free from the disease-engendering bilge-water which is always found in a wooden ship. Moreover, the use of iron masts, steel yards, and wire rigging, effects a very large saving of weight, and affords the greatest facilities for the application of patent reefing sails and other appliances, by which economy of labour is attained, and many risks of loss of human life avoided.

As to the form of building iron ships, and the manner of combining the iron so as to obtain the requisite amount of strength with the least amount of material, much difference of opinion exists among practical men. The angle iron frame and plating of the iron vessel take respectively the places of the timbers and planking of the wooden ship; and it has been found by experience that plating one-eight of an inch thick is equivalent in effect to planking of oak one inch thick, whilst plating 11-16ths of an inch thick is equal to planking of oak five inches thick. As in the largest American wooden vessels, the plank is seldom more than five inches thick; so it may be argued on the above data that the plating of the largest iron ship need not be more than 11-16ths thick; and that any strength required above that which such plating would give should be obtained by means of framework. Many practical men, however, advocate the system of light framework, and, in order to obtain the measure of strength necessary, the application of thicker plates. That the principle of strong framing and plating of moderate thickness is most advantageous, may be shown by many facts other than those which are derived from the most modern practice of wood shipbuilding. The strength of an iron ship, as in a girder, depends on its capability to resist the buckling and tensile strains that it is called on to bear. But I believe that we have, in reality, only to make a ship strong enough to resist the *buckling strain;* and I am led to this conclusion by experiments conducted

for that celebrated work, the Britannia Bridge, which proved that, in constructions of wrought iron, the resistance to the tensile strain is much greater than the resistance to buckle, and, in consequence, the upper parts of the girders are made much stronger than the lower parts. We have, in my opinion, to make the parts of an iron ship, in principle, like a girder. A girder, however, is at rest, but the strains are always in some known direction; but in a ship whose position is ever varying, it requires to be so constructed as to resist the strains in such varied positions. If the side of a ship could remain, as in a girder, constantly vertical, then the advocates for the thick plates and small frames might be able to show that their system was the most economical way to obtain the requisite strength, but as such side if laid over, as it is in a ship at sea, would without support, bend or buckle of its own weight, ***it is evident that the framing is absolutely necessary*** to keep the plating firm in position, and consequently the strength of the ship depends in a very great degree on the strength of the framing. Another fact that shows the economy of strong frames, is that a plate, with a piece of angle iron attached to its edge, would bear much more before buckling than a similar plate increased in thickness so as to weigh the same as the plate and angle iron. But the great and most important argument in favour of moderately thick plates and strong framing is, that all the work must be put together by hand; for though many attempts have been made to rivet ships by machinery, none seem yet to have been successful even in a mechanical point of view. So soon, therefore, as the thickness of plates and the size of the rivets pass the point at which the workmen with *ordinary* exertion can accomplish good work, then the attachment of the parts by means of rivetting is subject to the risks of imperfect workmanship. It is, therefore, my opinion, both in a practical and theoretical point of view, that we ought not to use plating in any vessel, however large, more than about three-fourths of an inch thick.

In the early period of iron shipbuilding, the frames were generally composed of simple bars of angle iron but they are now usually doubled by a reverse bar, which is rivetted on the principal bar, so as to make a frame, whose cross section is like the letter Z, and this form is perhaps as strong as any that could with economy be obtained. In some large ships plates of iron on edge were placed between the angle irons, so as to enlarge the section. The frame thus formed required longitudinal supports to bind it together, and those all important strengthening pieces,

called stringers, box and other keelsons were introduced. The great advantage of these appliances is that they may be placed exactly where the ship requires support, and that, too, with the least possible amount of iron. As to the application of these stringers and keelsons, the shipbuilder must be guided by the form, proportions, and other circumstances connected with the construction of the ship.

To show how far this system of longitudinal framing may be carried with success, I may point to the ship "Richard Cobden," designed by Mr. Guppy (known in connection with the construction of the "Great Britain"), in 1844. This vessel was framed so as to leave rectangular spaces to be covered with the outside plating; these spaces were 2½ feet vertically, and 5 and 6 feet horizontally, and in no part of this highly successful construction were the plates more than ⅝ths thick.

As to the rivetting, which is of the utmost importance in shipbuilding I shall say a few words. In making boilers, single rivetting is usually adopted, but there the strain is constantly in one direction. In ships, the direction of the strain is changeable as the vessel moves, therefore double, and in some cases triple, rivetting has been used with great advantage.

Mr. Fairbairn estimates that the tensile effect of single rivetting is represented by 56, double rivetting by 70, and triple rivetting by 90, and these proportions would appear to hold good, whether in chain or zigzag rivetting. The former, however, has been shown by experiment to have an advantage over the latter of about 20 per cent. in the tensile strain.

In concluding this necessarily brief account of the general principle on which iron ships are constructed, I may mention that the only objections that can reasonably be urged against ships made of this material are, that the compasses are difficult of adjustment, and that the bottoms get foul. Let us, however, hope that science, in the promotion of which the British Association is so powerful an agent, may in a short time show us how both these difficulties may be overcome.

I now proceed to what is perhaps the more interesting division of this paper, viz, a sketch of the progress of Iron Shipbuilding on the Tyne, Wear, and Tees.

For a very long period the district of the Tyne, Wear, and Tees, has been famous for its shipping. A committee of the House of Commons, that sat so far back as the year 1642, designated Newcastle as "the

nursery for shipping," and Defoe, writing of the Tyne in 1727, states that "they build ships here to perfection—I mean as to strength and firmness, and to bear the sea."

The history of iron shipbuilding in this district does not commence, however, until the year 1840. In March of that year, the "John Garrow," of Liverpool, a vessel of 800 tons burthen, the first iron ship seen in these rivers, arrived at Shields, and caused considerable excitement. A shipbuilding firm at Walker commenced to use the new material almost immediately, and, on the 23rd of September, 1842, the iron steamer "Prince Albert" glided from Walker slipway into the waters of the Tyne.

During the next eight or ten years very little progress was made. The vessels mostly in demand were colliers, and no one thought of applying iron in *their* construction. But, about the year 1850, the carriage of coal by railway began seriously to affect the sale of north country coal in the London market, and it became essential, in the interest of the coalowners and others, to devise some means of conveying the staple produce of this district to London in an expeditious, regular, and, at the same time, economical manner. To accomplish this object, I caused an iron screw steamer to be designed in such a manner as to secure the greatest possible capacity, with engines only sufficiently powerful to insure her making her voyages with regularity. This vessel (the "John Bowes"), the first screw collier, was built to carry 650 tons, and to steam about nine miles an hour. To the success of this experiment may be attributable, in a great measure, the present important development of iron shipbuilding in this district, and the fact that we continue to supply so largely the London market with coals. On her first voyage, the "John Bowes" was laden with 650 tons of coals in 4 hours; in 48 hours she arrived in London; in 24 hours she discharged her cargo; and, in 48 hours more she was again in the Tyne; so that, in five days, she performed successfully an amount of work that would have taken two average-sized sailing colliers upwards of a month to accomplish.

The amount of prejudice with which nautical men, and persons engaged in the shipping and coal trades, opposed the introduction of screw colliers was great. They argued that it would be impossible for steamers carrying 650 tons of coals, and costing about £10,000, to compete with vessels that consumed no fuel, and which, though carrying only half the quantity, cost little more than £1000, or only one-tenth the amount. I was, however, confident of the result, and persisted in the development of the system. How far my views have proved correct will be borne out by the following table, which shows the number of

cargoes and tons of coals imported into London by screw steamers in each year, from July 31, 1852 (the date of entry of the first screw steamer, "John Bowes"), to June 30, 1863.

Year.		Cargoes.			Tons.
1852	... ...	17	...	making	9,483
1853	... ...	123	...	"	69,934
1854	... ...	345	...	"	199,974
1855	Crimean War ...	174	...	"	85,584
1856	... ...	413	...	"	238,597
1857	... ...	977	...	"	547,099
1858	... ...	1127	...	"	599,527
1859	Italian War ...	899	...	"	544,614
1860	... ...	1069	...	"	672,476
1861	... ...	1299	...	"	851,991
1862	... ...	1427	...	"	929,825
1863	Half-year ending June,	714	...	"	463,609
					5,212,713

By this table it is seen that a total quantity of 5,212,713 tons of coals have been imported into London, by screw colliers, and, in addition to this, large and increasing quantities have been taken to other ports both in this country and abroad. Since its first introduction, too, the screw collier has been greatly improved, and the facilities for loading and discharging very largely augmented. The screw collier, "James Dixon," frequently receives 1,200 tons of coals in 4 hours, makes her passage to London in 32 hours, there—by means of the hydraulic machinery which our President invented, amongst the other inventions which distinguish his name—discharges her cargo in 10 hours, returns in 32 hours, and thus completes her voyage in 76 hours. The "James Dixon" made 57 voyages to London in one year, and in that year delivered 62,842 tons of coals, and this with a crew of only 21 persons. To accomplish this work on the old system, with sailing colliers, would have required 16 ships, and 144 hands to man them.

One of the great difficulties we had to encounter in perfecting these vessels was in the ballasting. To dispense with the necessity of shipping shingle or chalk as ballast, many costly experiments were tried, and at length, by a system of double bottoms, the construction of which adds to the strength of the ships, the ballasting of the vessels with water was brought to a highly satisfactory result. The water is allowed to run into the spaces between the two shells, as the vessels pass down the Thames; when the spaces are full the cocks are closed, and so remain until the arrival in the Tyne, when the water is pumped out by means of

an apparatus provided for the purpose. This system allows the vessel to be ballasted without loss of time at either end of her voyage, and does not impair in the slightest degree her power of carrying coals. The introduction of the screw collier has revolutionized the coal-carrying trade, and has had a most beneficial effect upon commerce generally. Besides accomplishing the purpose for which it was designed, this class of vessel has been proved capable of rendering very important services to the Royal Navy. When, in the latter part of the year 1854, information reached this country that the commissariat department of our army in the Crimea had broken down, and that the salvation of our troops depended upon a rapid despatch of supplies, it was found that screw colliers were admirably adapted for the work, and the majority of them were temporarily taken out of the coal trade and employed in the transport service. The Government admitted, on that occasion, that screw colliers had proved to be more useful and economical than any other class of vessels they had employed.

In the year following the launch of the "John Bowes," namely, in 1853, the first iron vessel built on the Wear, was released from its blocks. The Tees followed the example with great energy and considerable success, and on both these rivers, as we shall see presently, a very considerable trade in iron shipbuilding is carried on.

The first iron vessel, for war purposes, constructed in this district, was "The Terror," one of the large iron-cased floating batteries designed during the Russian War, to operate against Cronstadt. This vessel, of 2000 tons, 250-horse power, carrying 26 sixty-eight pounder guns, was built in three-and-a-half months, and she would have been completed in three months, had not the declaration of peace slackened the energies of our men, which, up to that time, had been maintained so nobly by their patriotic feelings.

It was in the building of this vessel that rolled armour plates were first used. The demand for forged armour plates was so great that the forges of the kingdom could not supply it, and recourse to rolling was unavoidable. At that time the largest plate mill was at Parkgate, and we accordingly employed Messrs. Beale and Co., the owners of Parkgate Works, to roll the plates we required. To the use of these rolled plates however, the Admiralty opposed itself; but we feeling convinced, by experiments which we made, that the rolled armour plates were, at least, equal to the forged, invited the Admiralty to a trial of their efficiency.

We built a target nine feet square, on a plan which we thought might be advantageously adopted for large vessels of war, and on the cellular

principle. The cells we filled with compressed cotton, which we had found by experiment to be very effectual in stopping shot. On this target was a thin teak backing; on the teak were bolted one hammered and two rolled plates. The target was bolted on to the side of an old wooden frigate at Portsmouth, under the direction of Captain Hewlett. The first shot fired at it missed the target, went through both sides of the frigate, and, to my great astonishment, skimmed over the surface of the water for nearly a mile. The firing showed that whilst the hammered plate split and cracked to pieces, the rolled plates were not broken, only indented, and were superior to the hammered plate in every respect. Unfortunately, the target was not firmly bolted to the vessel, and it sprung at each shot, so that the bolts which held the armour plates were broken, and they fell into the sea.

A shot was then tried to test the resisting power of the compressed cotton, and it appeared to answer so well that Captain Hewlett advised a series of experiments to be tried. The Admiralty were willing, but required us to provide the targets at our own expense. Having already spent upwards of £1000 on experiments for the good of the country, we declined this proposal; nevertheless, we had proved to the Admiralty this important fact, that the rolled plates were superior to the forged, and they have since been universally adopted. We claim, therefore, for this district the honour of being the first to prove the strength and utility of rolled armour plates, since known and spoken of in Parliament as "Palmer's Rolled Plates."

While on this subject of armour plates, I may, perhaps, be allowed, as the builder of the iron-plated frigate "Defence," to make a slight digression in order to express an opinion upon the class of marine architecture to which that vessel belongs. The "Defence," although in every respect a strong ship, does not combine all the strength which, with the same weight of material, might have been obtained; and with respect to her model, it is my opinion that if she had had less rise, and more floor, and so had drawn less water, she would have steamed faster, answered the helm quicker, and have proved in all respects more manageable and convenient. The Admiralty authorities, I know, do not agree in this view, and they are, at the present moment, spending a large amount of money in the national dockyards, for the express purpose of building a class of vessels similar in construction to the "Defence." In my opinion, it is, to say the least, very questionable policy for the Admiralty to speculate in this kind of shipbuilding. Private builders exerted themselves greatly in the production of armour-plated frigates for the

Government. These vessels were produced in much less time than would have been consumed in the Naval Dockyard, and in the matter of cost the difference must be greatly in favour of vessels built by contract. It is surprising to see the tenacity with which the Admiralty cling to wooden ships, notwithstanding the most overwhelming proofs that it is time to adopt iron exclusively.

It was my desire to furnish the Association with accurate statistical details of the iron shipbuilding trade of these northern rivers, showing the quantity of iron consumed, the number of men directly employed, and the amount of tonnage launched per annum. But, unfortunately, my neighbours here, and on the Wear and Tees, with a few exceptions, were too much engaged to supply me with the statistics of their respective establishments. I have, therefore, estimated the several totals from such materials, aided by personal knowledge and experience, as I was able to obtain, and the following statement will, I think, be a pretty close approximation to accuracy :—

	Tons.
Estimated amount of tonnage of iron ships launched on the Tyne during the year 1862	32,175
Ditto, on the Wear	15,608
Ditto, on the Tees	9,660
	57,443

The number of men annually employed in producing this quantity of tonnage, exclusive of those engaged in the manufacture of engines, was

	Men.
On the Tyne	4,060
On the Wear	2,500
On the Tees	1,550
Total	8,110

The quantity of iron consumed during the same period, in the construction of iron ships, was,

	Tons.
On the Tyne	22,540
On the Wear	9,360
On the Tees	6,760
Total	38,660

The amount of iron tonnage at present on the stocks in this district is as follows :—

	Tons.
On the Tyne	33,000
On the Wear	19,000
On the Tees	10,600
Total	62,600

But these statistics show us only the labour that is directly employed in the production of iron ships, and that, as we all know, is but a small proportion of the whole. It would, indeed, be difficult accurately to estimate the amount of labour that is indirectly concerned in this trade, as for instance in the manufacture of iron, the production of coals, the importation of timber, the construction of engines, and the supply of anchors, chains, sails, &c. Enough has been said, however, to prove that iron shipbuilding is one of the most important branches of industry in this great commercial and manufacturing district.

I may, perhaps, be allowed to describe very briefly, the operations of my own firm, which, I trust, will prove of some interest, as showing the extent to which one establishment may be developed. In the first place, we obtain the greater portion of our ironstone from our own mines. At a point on the coast, 10 miles north of Whitby, the ironstone seams crop out in the sides of the cliffs, and here we have formed the small harbour of Port Mulgrave, where vessels can ride in safety, and ship their cargoes with ease and expedition. Between the Tyne and Port Mulgrave, some of our steamers run direct, making on the average four voyages per week, whilst others of a larger class call to load stone on their return voyage from London. At Jarrow, the ore is delivered to the furnaces by means of the Armstrong hydraulic cranes, and mixed with ores from Cumberland, Devonshire, and Lincolnshire, thence it is passed to the mills, and from the mills to the ship-yards. The number of men employed in these operations is upwards of 3,500. The number of tons of iron consumed per annum in our yards and engine works is about 18,000 tons. The amount of tonnage launched during the year ending the 1st August was 22,000 tons. We have 15,000 tons in course of construction, and orders spread over a period for 40,000 tons more. Amongst these latter are steamers of upwards of 3,400 tons burthen, pronounced by their owners to be "the finest and most complete merchant steamers ever built." They are intended to bring cotton from the Southern States of America, so soon as the unhappy war in that country shall cease, and they will no doubt be but the pioneers of others of a similar class. One of these steamers is of sufficient capacity to carry 7,000 bales of cotton, and it is estimated that, during one year, she will bring from New Orleans to Liverpool 38,000 bales. The crew of such a vessel consists of sixty hands, and it would require five sailing vessels of 1,200 tons each, employing 130 seamen, to do the same work.

A consideration of the future of the iron shipbuilding trade opens out a vast field for speculation; but the ultimate result is not difficult to

anticipate. We have seen with what success sailing vessels have been superseded by steamers in the coasting and coal trades, and we know that magnificent fleets of steamers, engaged in the postal and other services, are ploughing almost every known sea. As commerce increases, there will be few trades in which the employment of iron steamers will not be found of advantage. Most of the carrying trade to the Baltic and Mediterranean is already conducted in vessels of that class, and the sailing ships that cross the North Atlantic are being rapidly displaced by iron steamers. Their advantages in strength, speed, and capacity, are so marked, that sailing vessels of timber must give way before them. Even the Admiralty, cautious and unyielding though it be, will have to abandon its "wooden walls" in favour of the stronger and more useful material; a material, too, that lies in rich profusion beneath our feet, and has not, like timber, to be purchased of other nations. The commercial men of this country have set the Admiralty a signal example of industry and enterprise. It is they who have made the experiments, and adopted the inventions that have established the maritime supremacy of this country; and it is owing to their energy that we find on every sea, in the shallow rivers of the east, and the deep broad waters of the west, English-built ships of commerce diffusing the benefits of free trade, and linking nations and tribes together in the bonds of amity and peace. The true source of our national greatness is to be sought in this wonderful development of our merchant navy. Other nations are entering into friendly rivalry with us, but the larger share of the carrying trade of the world will ever be secured to that country that can produce vessels combining the largest capacity with the utmost amount of economy and expedition in construction, and that can, at the same time, navigate those vessels with the greatest degree of skill and rapidity.

In conclusion, permit me to express the proud conviction I entertain that the mineral wealth of this district, and the skill and endurance of its workmen, whether on land or sea, will enable the locality that gave birth to an Armstrong and a Stephenson to maintain its character for maritime industry and enterprise, and to bear its full share in promoting the commercial greatness of the country.

APPENDIX.

IRON SHIPBUILDING.

When the foregoing paper was written, the statistics relating to iron shipbuilding on the three rivers were confined to the year 1862, but were sufficient to show the important position this trade occupies in the manufactures of the district, and how rapid had been its advancement. During the present year 1863, however, the increase in this particular branch of local industry has far exceeded the most sanguine expectations, as the following figures will testify :—

AMOUNT OF TONNAGE OF IRON SHIPS LAUNCHED DURING THE YEAR 1863, AS COMPARED WITH 1862.

	1863.		1862.
On the Tyne	51,236	...	32,175
On the Wear	25,000	...	15,608
On the Tees	15,060	...	9,660
	91,296		57,443

ESTIMATED VALUE OF THE ABOVE.

	1863.		1862.
On the Tyne	£922,248	...	£546,975
On the Wear	450,000	...	265,336
On the Tees	271,080	...	164,220
	£1,643,328		£976,531

QUANTITY OF IRON CONSUMED IN THE CONSTRUCTION OF IRON SHIPS DURING THE YEARS 1863 AND 1862.

	1863. Tons.		1862. Tons.
On the Tyne	32,170	...	22,540
On the Wear	15,697	...	9,360
On the Tees	10,539	...	6,760
	58,406		38,660

These figures show an aggregate tonnage of 91,296 tons, making a total value of £1,643,328, exclusive of the engines ; and a total of 58,406 tons of iron consumed last year in iron shipbuilding on the three northern rivers. They show, moreover, that, with the single exception of the coal trade, iron shipbuilding is the most important branch of industry in this great commercial and manufacturing district.

December 31*st*, 1863.

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ON

THE ENGINEERING MANUFACTURES
OF THE DISTRICT.

BY

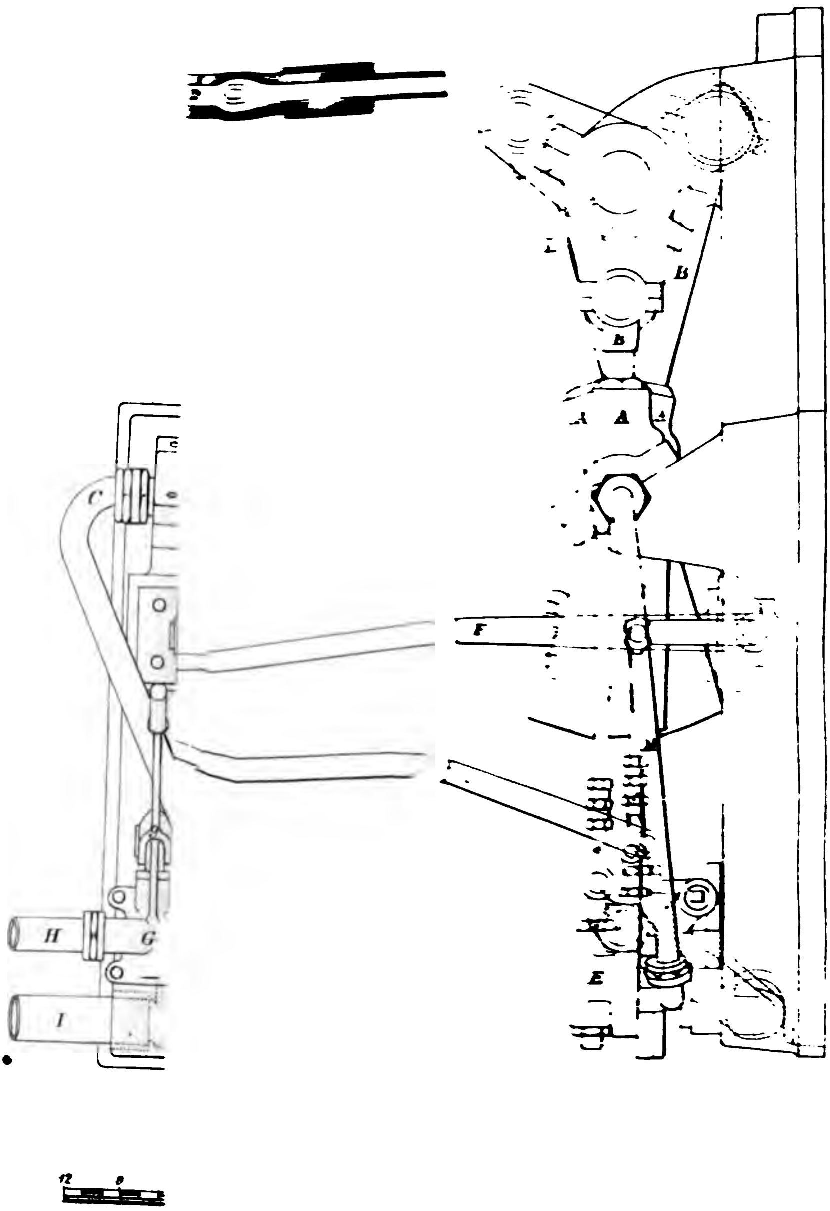
P. WESTMACOTT, C.E., M.I.M.E.,

AND

J. F. SPENCER, M.I.M.E., M.I.E.S.

O O

A. The cylinders.
B. Ram with Piston.
C. Passage to larger are
D. do. smaller d
E. Valve case.
e. Working Valve Spindl
f. Power do. do.
F. Hand lever for Power
G. Regulating Valve.
g. do. do. lev
H. Pressure pipe.
I. Exhaust do.



ON

THE ENGINEERING MANUFACTURES.

THE north-eastern districts of the United Kingdom, long preëminent for mining operations in coal, and more latterly in ironstone, have also been gradually rising in importance as the seat of most extensive engineering manufactories.

The unlimited supply of coal, an intelligent, hardworking, and enterprising population, together with the engineering necessities of such a large mining district, and convenient seaports, have combined to create an increasing demand for all classes of engineering manufactures.

As early as the year 1747, the Gateshead Iron Works were commenced, and the present proprietors, Messrs. Hawks, Crawshay, and Co., have now one of the largest engineering establishments on the Tyne.

In 1793, millwright work was undertaken at Chester-le-Street, paper, lead, corn, and other mills being constructed and supplied to all parts of England, Scotland, Ireland, and abroad; in 1826, a large foundry business was added.

In 1809, the Walker Iron Works, owned by Messrs. Losh, Wilson, and Bell, were commenced, and, as in the two establishments previously mentioned, the variety and extent of engineering work rapidly increased, as the demand arose for an improved class of machinery and motive power.

Mr. Losh, the late senior partner of the firm, is well known in connection with the introduction of wrought iron railway wheels—an improvement that has materially tended to perfect the efficiency of the rolling stock. The manufacture of Losh's patent wheels was at one time a very important branch of the Walker Iron Works.

It may be interesting to notice, at the early date of 1784, the erection on the Tyne of one of Watt's steam engines for the owners of Walker Colliery, by Boulton and Watt. Mr. Losh purchased this engine in 1805, for the Walker Alkali Company, and it may yet be seen working

daily at Walker, with its wooden beam and bed plate, and sun and planet crank motion.

In 1817, Mr. Robert Hawthorn, the present senior partner of Messrs. R. and W. Hawthorn, established the Forth Bank Engine Works, receiving as a partner his brother William, in 1820. The increase from eight men in 1817 to nearly 1000 in 1863, indicates very forcibly the progression of this well known establishment. (See Table B.)

In 1830, Mr. T. D. Marshall, of South Shields, commenced the building of steam-tugs, and fitting them with machinery.

In 1838, the Hartlepool Iron Works were established by Messrs. Thomas Richardson and Sons. These works are now of considerable magnitude.

In 1844, the Tees Engine Works, now owned by Gilkes, Wilson, and Co., were established for the manufacture of large iron bridges, and similar constructions, locomotives, marine and stationary steam engines, and foundry work.

In 1847, the Elswick Engine Works were commenced with about 200 men, and although then only engaged in the manufacture of hydraulic and general machinery, there has been a later period (1858), when, with the manufacture of the Armstrong guns, the number of hands employed has amounted to upwards of 4000.

In 1847, Mr. Renoldson, of South Shields, established shops for the construction of engines and boilers for tug steamboats.

As the increasing commercial interests of this country, and the improvements matured in steam power, gave a fresh impetus to engineering manufactures, the undoubted advantages and facilities of this district were appreciated and availed of by Messrs. Palmer Brothers, in 1852; Messrs. Morrison and Co., in 1853; Messrs. Thompson, in 1856; and Mr. David Joy, of Middlesbro', in 1862.

In referring briefly to the progress and present condition of the engineering manufactures of the Tyne and neighbouring districts, it will be necessary to classify them under the following heads:—

1.—General machine and mill work.
2.—Stationary and steam engineering.
3.—Locomotives.
4.—Marine engineering.
5.—Hydraulic machinery.
6.—Iron bridges, viaducts, lighthouses, &c.

1.—GENERAL MACHINE AND MILL WORK.

During the past 116 years, the following firms have contributed largely to the supply of first-class machine and mill work of all descriptions:—

Messrs. Hawks, Crawshay, and Co., Gateshead Iron Works.
Messrs. Thomas Murray and Co., Chester-le-Street.
Messrs. Losh, Wilson, and Bell, Walker Iron Works.
Messrs. R. and W. Hawthorn, Forth Bank Engine Works.
Messrs. R. Stephenson and Co., South Street Engine Works.
Messrs. Thomas Richardson and Co., Hartlepool Engine Works.
Messrs. Gilkes, Wilson, and Co., Tees Engine Works.
Messrs. W. G. Armstrong and Co., Elswick Engine Works.
Messrs. Morrison and Co., Ouseburn Engine Works.
Messrs. Thompson and Co., Spring Garden Engine Works.

With reference to the magnitude of the work undertaken by some of the above firms, it may be stated of Messrs. Hawks, Crawshay, and Co., Messrs. Losh, Wilson, and Bell, Messrs. Thomas Murray and Co., Messrs. W. G. Armstrong and Co., and Messrs. Morrison and Co., that single castings have been supplied from 45 tons downwards, and there are capabilities for castings of even 60 tons.

As every description of paper, corn, lead, and other mills have been extensively constructed, it is impossible to refer to them in detail; but, in point of date, the erection of a self-acting crane, for delivering ballast, at St. Anthony's Quay, by Messrs. R. and W. Hawthorn, in 1820, is worthy of notice.

2.—STATIONARY STEAM ENGINEERING.

Steam power was first practically utilized in mining operations, and its application was early introduced in the north-eastern mining districts by several of the engineering firms before referred to; and the fact that the wants of a large mining district were almost exclusively supplied by local talent and capital, is a satisfactory proof that there were the right men at the right time, to aid, by their engineering experience, the resources and trade of the district.

Among the engineering specialities of this district, may be mentioned many large winding and blowing engines. Messrs. Hawks, Crawshay, and Co., have cast and bored cylinders of 108 inches diameter for this class of engine.

In 1822, Messrs. R. and W. Hawthorn first applied steam to drive their lathes, and in 1824 they constructed a 50-horse power engine for

the Plate Glass Works of Messrs. Cookson and Cuthbert, and this engine is still doing efficient duty. At this period the same firm also fitted a self-acting *steam* crane for delivering ballast at Hebburn Quay, on the Tyne.

Several of the firms previously mentioned have extensively supplied steam cranes of varions powers—Messrs. Thompson and Co. alone having made upwards of 200.

Messrs. Morrison and Co. are noted for their steam hammers, which they have extensively supplied to the Government, the Elswick Engine Works, and other large establishments; and they have them in their works of 15 to 20 tons weight, together with two steam cranes capable of lifting 50 tons each.

Although not quite finished, yet, on account of its excessive magnitude, it is of some interest to note here, that Messrs. Morrison and Co. are now engaged in completing a monster steam hammer for the Russian Government. The forging for the hammer is 40 tons, and the enlarged part of the same is 6 feet 6 inches diameter, finished size. The total weight of this hammer, when completed, will be about 550 tons; the bed alone being 240 tons, and will be cast in three pieces, in its final resting place. It is believed this will be considerably the largest steam hammer in the world.

The application of steam power to underground haulage has been successfully introduced by Messrs. Thomas Murray and Co., of Chester-le-Street, the steam being conveyed to engines underground from boilers placed above the surface.

A model of this application of steam power in Hetton Colliery will be exhibited at the meeting. In this case there are a pair of 18-inch cylinders and 3 feet stroke, working four drums, all on separate shafts, for drawing on a plane and incline.

Messrs. Murray and Co. have lately erected two 200-horse power high-pressure condensing engines for winding at Ryhope New Winning; the cylinders are 68 inches diameter and 7 feet stroke. These engines can deliver 2,000 tons per day, from a depth of 300 fathoms. Also, at North Seaton, a winding and pumping engine, cylinder 60 inches diameter and 7 feet stroke, fitted with the first hollow plate iron beam.

Messrs. Losh, Wilson, and Bell were early in the field in the construction of steam engines for mills, collieries, and iron works. This firm erected a large pumping engine about thirty years ago for Friars Goose. Also, at later dates, a large pumping engine for the North

Seaton Colliery—diameter of cylinder 76 inches, and 8 feet stroke; 60-inch double cylinder high pressure engine for the Burradon Colliery and many engines for blast furnaces and winding, having steam cylinders of 38, 40, and 42 inches diameter. At the present time this firm is largely engaged in the manufacture of surface condensers for mill and other steam engines, in connection with Mr. J. F. Spencer, the patentee of certain improvements in their application to existing and new engines. This short and limited notice of such an important subject as the development of stationary steam engineering can only serve to indicate in a very limited degree the engineering capabilities of the district.

3.—LOCOMOTIVE ENGINEERING.

To the north-east of England belongs the undoubted honour of being the birthplace of the locomotive; and this fact must ever be recorded when the names of Trevethick and Stephenson appear on the page of history. In a paper written expressly to record contributions to the engineering talent of the country, it would be simply unjust to forget in the now almost world-wide extension of locomotive manufacture, the Stephenson "Rocket" of 1829, or the Hawthorn "Comet," of 1835. The latter engine, which was used at the opening of the Newcastle and Carlisle Railway, can still be seen in daily work, at the saw mills of the Forth Bank Engine Works. During the past 34 years, upwards of 2,400 locomotives have been constructed by Messrs. R. Stephenson and Co., Messrs. R. and W. Hawthorn, Messrs. Gilkes, Wilson and Co., and Sir W. G. Armstrong and Co. In the above number are included all the known varieties of the locomotive, from the comparatively small tank engine to those magnificent specimens constructed by Messrs. R. Stephenson and Co., for the late Viceroy of Egypt.

4.—MARINE ENGINEERING.

It would display an unwarrantable indifference to the birth and progress of great improvements, if reference was not made to the first practical application of steam power on the Tyne, for towing purposes, more especially as the date of such application was almost coeval with Henry Bell's "Comet" on the Clyde, in 1812. It is also of interest in an engineering point of view, to place on record the names of those local firms who were earliest in the field in making and fitting the first steam engines for Tyne tugs.

In 1814, the first steam tug, the "Perseverance," was fitted and

started on the Tyne, there being at that time only 17 steam boats in existence. And Table C gives the particulars of the introduction of steam for towing purposes on the Tyne, from 1814 to June 1822. In this table it will be seen that the now existing firms of R. and W. Hawthorn firstly, and Hawks and Co. secondly, made and fitted steam engines for tugs as early as the years 1820 and 1821. This reference to the beginning of steam navigation and manufacture of marine engines on the Tyne, is the more important from the well known fact, that almost all the ports of the United Kingdom, as well as those of foreign countries, have, to the present day, come to the Tyne for their steam tugs. It may, therefore, be fairly assumed that the Tyne engineers have, from the first, supplied a most important want in a manner that has defied competition; and even now it is difficult to suggest any important improvement in the class of engine that has been working in these tugs during the past 40 years.

Some additional force is given to the last statement, by the fact, that at the present time there are upwards of 250 of what may be aptly termed "native steam tugs" employed on the Tyne, besides nearly 100 more in the ports of Sunderland, Stockton, Middlesbro', and Hartlepool, and the engines in these are almost identical in type with those fitted in 1820.

Among the evident causes for the rapid extension of marine engine construction in the ports of this district are the early introduction of steam power for towing purposes, and more lately the increasing substitution of steam for sails in the coal carrying trade, leading to the introduction of screw colliers. These latter may be fairly considered, with reference to this district, as native productions; and, furthermore, they have proved stepping-stones to the construction of the higher classes, and larger powers of marine engines.

As before stated, Messrs. R. and W. Hawthorn were the first of the now existing firms to make engines for steamboats, and during the past 10 years especially, they have been extensively engaged in fitting marine engines, both paddle and screw, up to 250-horse power. In 1859 they applied Mr. J. F. Spencer's system of surface condensation most successfully to the "Frankfort," 100-horse power, of Liverpool, and they have more lately applied the same arrangement, with equal success, to a pair of 140-horse power screw engines, which they made and fitted into the "London," for the Cadiz trade, the economy of fuel being considerable.

The same firm have also supplied Her Majesty's Government with 150-horse power horizontal screw engines for H.M.S. "Shearwater."

These engines are fitted with separate expansion valves, worked by a second link.

Messrs. Hawks, Crawshay, and Co. have constructed several pairs of marine engines, paddle and screw, for river and sea service, and they date the commencement of this class of work as early as 1821.

In 1830, Mr. T. D. Marshall, of South Shields, commenced building and fitting steam tugs, and out of the 600 engines his firm have made since that date, upwards of 300 have been fitted in steam tugs; Marshall's steam tugs being well known in every port. The present firm of Marshall Brothers are still largely engaged in the construction of paddle and screw engines.

The names of Renoldson, Almond, and Hepple, are also well known as producers of steam tug engines on a large scale, and it may be safely stated that upwards of 1000 tug engines have been made and fitted on the Tyne.

Messrs. Thomas Richardson and Co., of Hartlepool, have paid much attention to marine engineering, and are now engaged in perfecting several improvements therein. The extent of their establishments can be seen by reference to Table A.

Messrs. R. Stephenson and Co. have employed a large portion of their extensive establishment in the construction of marine engines, and, in addition to a long list of engines fitted, of various powers, they put on board a Sardinian frigate a pair of 250-horse power horizontal screw engines for the Sardinian Government.

In 1852, Messrs. Palmer Brothers established the Jarrow Engine Works, where have been manufactured, and fitted on board, a considerable number of marine engines, paddle and screw, and some of them of large power, having 90 and 80-inch cylinders. During the past eighteen months this firm has introduced surface condensation into several pairs of engines, adopting an American plan for jointing the tubes. These engines are reported satisfactory for duty and economy of fuel, and there are several pairs in hand on the same plan, having 63 and 60-inch cylinders. Of the latest and most successful of this firm's engines, may be mentioned those of the "Georgia," having 60-inch cylinders, giving a high speed, and small consumption of fuel.

Messrs. Morrison and Co., of the Ouseburn Engine Works, have given much attention to the construction of marine engines up to 250-horse power, and have applied Hall's condensers, separate expansion gear, and steam jackets, with much success.

The mail steamship "Auckland," with the improved engines referred to, of 150-horse power, has proved, on her trial, an economical and successful ship.

Messrs. Thompson and Co., of the Spring Gardens Engine Works, have, especially since 1856, been largely engaged in the construction of marine engines up to 200-horse power, and they also have paid attention to economy of fuel.

Messrs. Gilkes, Wilson, and Co., of Middlesbro', and Mr. G. Clark, of Sunderland, are also engaged in marine engine construction, but have not furnished any information as to extent or speciality.

In this limited notice of what is now a most important branch of engineering industry in this district, it is important to state that the north country engineer has to provide a larger and more powerful marine engine, at a less cost per horse power, than the engineer on the Thames, and this unjust difference has tended materially to check in this district the manufacture of the higher class of marine engines.

Finally, it may be confidently stated there is a general desire among the north country engineers, that *quality of workmanship following price* should be superseded by *price following quality of workmanship.*

Several of the large firms referred to have every capability, in extent and covenience of shops and tools, for supplying the largest engines that may be required for Her Majesty's Navy or mail steamships.

5.—HYDRAULIC ENGINEERING.

It will be necessary under this head to refer separately—first, to the application of machinery for removing or supplying water; and secondly to the application of machinery in using water as a motive power.

Extensive mining necessities require the constant attention of the mechanical engineer, especially to provide large and capable machinery for discharging water from great depths; and it is a matter of much satisfaction when such machinery can be designed and applied on the spot.

The following brief reference to the productions of local firms, in addition to the supply of machinery for water-work, &c., will clearly show that this district has reaped the full benefit of such local designs and applications.

Messrs. Thomas Murray and Co., of Chester-le-Street, have applied steam power extensively to pumping for colliery purposes, and completed some of the largest colliery pumping engines in the district, some of them being 200-horse power, with 60 and 68-inch steam cylinders.

Messrs. R. and W. Hawthorn were very early in the field in the construction of large engines for pumping, and in 1834 they erected a single acting pumping engine, with 55-inch cylinder and 8 feet stroke, for the Newcastle Subscription Water Company. This engine was the first erected in the neighbourhood with steam jackets and valves, on the Cornish principle. It was at a later date (1854) converted into a double acting engine, and is now doing duty at Newburn.

In 1845, several large pumping and winding engines were erected by the same firm, at the various collieries in the North of England, among which was a powerful pumping engine of 250 nominal horse power, at Walbottle Colliery, on the Tyne, with steam cylinders 77 inches in diameter, and 10 feet stroke. It was erected to drain a large coal-field area, where it is now working.

In 1847–8, several first-class water-works engines were manufactured and erected by the same firm, in the towns of Newcastle, Derby, Nottingham, Wolverhampton, and Brighton; and in 1858–9 they erected powerful double acting, combined, high and low pressure, rotative, beam engines, at the works of the Nottingham Water Works Company, the Coventry Water Works Company, and at Altona, near Hamburg, for the supply of that city with water, under the direction of Thomas Hawksley, Esq., C.E. These last-named engines performed a duty of 110 millions, with 112 lbs. of coal, the consumption being only 2¼ lbs. per indicated horse-power. An arrangement, by which the governor was made to act directly upon the steam valves, was introduced in these engines with perfect success, securing great steadiness in working, and effecting a considerable saving in the quantity of steam used.

Messrs. Hawks, Crawshay, and Co., of Gateshead, have constructed and erected at the Hull Water Works, the largest pumping engine that has been made in this district. The steam cylinder is 85 inches diameter, and stroke 10 feet 6 inches, the plunger pump being 34¾ inches diameter, and the same stroke as the steam cylinder. This beam engine is single acting, and capable of lifting nearly two tons of water 174 feet high each stroke. The same firm has also erected a large pumping engine for the Water Works at Scarborough. The steam cylinder is 45 inches diameter, and stroke 8 feet. This is a single acting beam engine, worked expansively.

Messrs. Morrison and Co., of the Ouseburn Engine Works, have made several large pumping engines. One pair was erected at Cleadon Lane, for the Sunderland and South Shields Water Company. There are two

steam cylinders, each 60 inches diameter, and stroke 8 feet, worked expansively.

Messrs. Losh, Wilson, and Bell have also erected several large colliery pumping engines.

Sir William G. Armstrong and Co., in addition to their extensive application of machinery for applying water as a motive power, have constructed the engines for the Durham Water Works, together with other pumping engines for collieries, and they have successfully introduced a self-acting valve in water-works supply pipes, which effectually shuts off the supply in the case of a pipe bursting.

Of the second division, or the use of water as a motive power, there is a special manufacture by Sir W. G. Armstrong and Co., at the Elswick Engine Works, and the following somewhat full reference to this subject may be justified by the fact, that the manufacture of this class of machinery has been exclusively confined to this district.

At the meeting of the British Association for the Advancement of Science, held in the year 1854, Sir William (then Mr.) Armstrong read a paper on the "Application of Water Pressure Machinery," wherein he described the origin and principles of his invention in the system of hydraulic machinery. Since that period many improvements have been introduced, but the principles effected remain the same.

The application of water power is classed under two conditions—viz., the one where the pressure is obtained from natural sources, the other where it is generated by artificial means. The employment of a natural supply has remained limited, owing to such supply being confined to districts generally unfavourable for the erection of works, and the important and extended application of hydraulic machinery which has taken place in nearly all the principal docks, railways, and government establishments in this country, is due to the invention of the "accumulator" for producing artificial pressure, usually made equal in effect to a head of water of about 1500 feet.

This high-pressure system has been adopted with economy to a great variety of purposes, such as to cranage, wagon lifts, coal drops, hoists, and tipping machines, to the working of turn-tables, traversing machines, hauling machines, capstans, &c., &c., but in no one branch of labour, perhaps, has this economy been more exemplified than in the loading and discharging of vessels, particularly those employed in the coal trade.

Nearly 1800 hydraulic cranes, hoists, and other machines of this description have been applied, and 174 steam engines, having a collective

power of more than 5,200 horse power, are employed in supplying the pressure required for working them. In addition to these, 177 hydraulic engines of various forms and powers have been produced, and 23 moveable bridges are worked by hydraulic machines.

The most novel and noticeable arrangement, for the discharge of coal from vessels, by means of hydraulic machinery, is to be seen on board a vessel belonging to Mr. Cory, moored in the river Thames. This vessel, originally built for other purposes, has been converted into a floating wharf, and is supplied with a steam pumping engine, accumulator, six hydraulic cranes (which weigh the coal at the same time), two hydraulic capstans, and a variety of appurtenances for facilitating the work by day and by night.

Rapidity of discharge is the great feature of this scheme. Steam colliers carrying 1200 tons of coal are delivered in 10 hours. Such vessels plying between the Tyne and the Thames have accomplished the voyage there and back in 96 hours, having loaded and discharged each cargo in one tide, and made the passage in three tides each way. Two such vessels can be delivered at the same time alongside Mr. Cory's floating wharf, thus rendering the power equal to the discharge of about 5,000 tons of coal in 24 hours.

The application of hydraulic hoists for shipping coal has met the difficulty formerly felt in loading from low levels, at a comparatively moderate cost, as may be seen from the following figures :—

At the Newport Docks, Monmouthshire, in the year 1862, 219,485 tons of coal were shipped from three hydraulic hoists, worked by six men. The sum paid in wages, stores, and repairs, amounted to £501 6s. 2d. The cost of supplying the pressure amounted to about £250, which gives a charge of about 0·276 of a penny per ton for the pressure, and 0·552 of a penny per ton for wages, stores, and repairs. These figures are exclusive of the interest upon the outlay of capital. Before the introduction of hydraulic machinery at these docks, the cost of loading coals by hand amounted to between 5d. and 7d. per ton.

In point of despatch, the hydraulic is equal with the gravitation system, both being limited by the labour of trimming the coal in the hold of the vessel.

The most remarkable application of a hydraulic machine for loading coals is the one now constructing at Goole Docks, in connection with the system adopted by Mr. Bartholomew for the coal traffic upon the Aire and Calder Canal. The barges, carrying 33 tons of coal each, will be

lifted by this machine out of the water, and their contents tilted directly into the hold of the vessel to be laden.

Recent improvements in the construction of rotatory engines have so simplified their form and reduced their size, that the general application of this class of engines is rapidly extending. A 7-horse power hydraulic engine, worked from the ordinary high (accumulator) pressure, occupies a space of two and a quarter feet square by nine inches deep. Such engines are now being applied directly to new, as well as to the existing dock-gate crabs at the Liverpool Docks, without at all disturbing the present arrangement of the hand-power gear of these crabs, which can thus still be used by hand in cases of emergency. Other engines are similarly applied directly to the crabs of hand-power cranes, swing bridges, and other hauling appliances; to capstans, machines for planing armour plates, &c. The latest improvement in hydraulic engines consists in making them with variable power, so that their consumption of water may be the better proportioned to meet any fluctuations in the amount of work to be done. An engine of this description, capable of being worked up to 17-horse power, under an ordinary (accumulator) pressure of 700 lbs. per square inch, is exhibited in the collection of models brought together in the Central Exchange News Room during the present meeting of the Association.

The advantage of the system of storing up pressure in accumulators, so that a great force can be quickly brought to bear upon heavy masses to be rapidly moved for limited distances, is well exemplified in its application to moveable bridges, and the importance is the more felt in situations where traffic would be seriously impeded by slow action, as for instance, at the part of the Swansea and Neath Railway where the line crosses the mouth of the river, and the entrance to the dock in Swansea. The communication of the line is kept up over these two points by hydraulic draw-bridges. The time occupied in lifting and drawing back the largest bridge, which has a space of 75 feet, and weighs 260 tons, is under $1\frac{3}{4}$ minutes. At Wisbeach, where the plan of storing up pressure in an accumulator by hand pumps is resorted to, a bridge, weighing 450 tons, can be opened or closed in less than two minutes.

In noticing the application of water pressure, derived from natural sources, to the working of machines upon the system introduced by Sir Wm. George Armstrong, no better reference can be made than to the complete and extensive works erected upon the lead mines at Allenheads. Hydraulic machinery is therein employed in raising the minerals from the

mines; in giving motion to machines for washing, separating, and crushing ore; in pumping water, and driving saw mills and the machinery of a workshop.

The most recent application of water power at these mines deserves especial notice. The district upon which several new works are opened is void of falls of sufficient altitude for working the engines and machines directly, but a river runs through the district which is suitable for overshot wheels, and through such mediums the stream is made to force water into accumulators, thus generating an intensified power, which is utilized by compact machines distributed in situations most convenient for their several duties. The principal objects sought in thus intensifying the pressure is to lessen the size of the pipes, cylinders, and valves of the machines and to gain more rapid action, and also by so reducing the size of parts, to effect a saving in outlay upon the work generally.

6.—IRON BRIDGES, VIADUCTS, LIGHTHOUSES, &c.

The art and manufacture of iron bridge building, and of other similar iron structures, which form such an important feature in railway construction and harbour improvements, are followed to a considerable extent by several engineering firms in this district.

The following brief notice of some of the most important of these works can only be taken as an index of the resources of the district in this direction.

That noble structure which spans the river Tyne, and forms a communication of road and rail at a high level between the towns of Newcastle-upon-Tyne and Gateshead, emanated, as is well known, from the same practical mind and genius that, with dauntless courage and rare skill, threw railway bridges across the Menai Straits and the St. Lawrence River.

The superstructure of the High Level Bridge was executed by Messrs. Hawks, Crawshay, and Sons, of Gateshead. This firm has recently erected the cast-iron bridge at York, from the designs of Mr. Page. It spans the river Ouse in one arch of 172 feet in width. Also the new bridge at Sunderland, which consists of a single arch of about 237 feet span, at a level of about 90 feet above high water mark. A melancholy interest is attached to this bridge, it being one of the very last works designed and undertaken by the late Robert Stephenson.

Messrs. Hawks, Crawshay, and Co. likewise constructed the wrought iron gates for the Northumberland Docks, and the iron lighthouses at

Gunfleet, Calais, and Harwich, and supplied the materials for the iron pier at Madras, a work of considerable magnitude.

Messrs. Robert Stephenson and Co. have been engaged upon the construction of wrought iron gates for docks, and have made 38 wrought iron bridges, among which, as most noteworthy, may be mentioned the Kaffie Azzayat Bridge over the river Nile. The total length of this bridge is 1607 feet. It is composed of eleven fixed openings, each 114 feet wide, and two swing openings, each 80 feet wide. The girders are box shaped, and are carried upon wrought iron cylinders, 10 feet in diameter and about 90 feet long. The gross weight of this bridge, with the supporting cylinders, amounts to 2634 tons.

The firm of Gilkes, Wilson, and Co., of Middlesbro', have recently executed, from the designs of Mr. T. Bouch, some lattice bridges for the South Durham and Lancashire Union Railway, of a peculiar light and cheap construction. Of these the Beelah Viaduct may be looked upon as the most interesting specimen of construction and workmanship. (Several models of this bridge are exhibited at this meeting.) It is constructed upon a somewhat similar plan to the celebrated Crumlin Viaduct, from which, however, it differs in many essential points. This Beelah Viaduct consists of fifteen pieces, composed of hollow columns. The span of the lattice girders forming the roadway is 60 feet in width. The total length is 1000 feet, and the greatest depth, from the rail to the ground, is 195 feet. The quantity of materials used in construction consists of 776 tons of cast iron, 303 tons of wrought iron, 12,343 cube feet of Memel timber for roadway.

Sir William G. Armstrong and Co. have been engaged extensively in designing and manufacturing iron bridges. They have constructed 25 moveable and 44 fixed bridges. With one or two exceptions, the whole of the former are worked upon the hydraulic system introduced by them.

The swing and draw bridges of the Birkenhead, Liverpool, and London Docks, and upon the Swansea and Neath and Great Western Railways, are among the most noteworthy of this class. The largest fixed bridge constructed by this firm is the one which crosses the river Somme, in India, made after the plans of Mr. G. Rendel, now one of the partners of this firm. Being about one mile in length, it boasts of being the longest bridge but one in the world. It is formed with 28 spans. The girders, carrying a railway platform above, and a common roadway beneath, are of the lattice construction, the top section being composed of wrought

iron boxes, and the lower section of tension bars. The girders are carried upon brick piers. The total weight of this bridge, including the pier superstructures, which are of iron, is about 4000 tons. Sir W. G. Armstrong and Co. have also turned out from their works, caissons, dock gates, pontoons, coffer-dams, saddle-back barges, wrought iron dredgers, and a variety of works of this description.

There are many other firms in the district engaged in constructing classes of work similar to those before referred to. Enough, however, has been said to show the important position which this district holds in a branch of industry, the history and development of which have been shortly traced in this paper.

TABLE A.—APPROXIMATE STATISTICS OF ENGINEERING MANUFACTURE IN THE NORTH EASTERN DISTRICT.

Number.	Manufacturers. Name.	Manufacturers. Address.	Date of establishment of Works.	Description of Work executed.	Total number of hands employed.	Total number of Engines, Boilers, Machines, or Mills, completed since the commencement of their works.	Horse-power of said Engines and Boilers.	Quantity of Raw Materials used in the construction of the said Engines and Machinery.	Approximate value of Raw Materials.	Estimated value of Work turned out per Annum.
								Tons.	£	£
1	Hawks, Crawshay & Co. ..	Gateshead	1747	Millwork and general Machinery, Waterworks, Mill, Colliery, and Marine Steam Engines, Bridges, &c	1500	92 Marine Engines .... 58 Land Engines	5000 in 30 years.	......	......	225,000
2	Murray & Co...............	Chester-le-Street ..	1793	1793 to 1826, Paper, Lead, and Corn Mills, Agricultural Machines and Water Wheels. 1826, Engine Building and Cast Iron Foundry. 1841, Boiler Making, Underground Hauling Engines	200	350 Stationary Engines, 500 Boilers, 400 Corn, Clay, Tread, and Lead Mills, Brickmaking Machines, and Waterwheels	15,000 Engines. 10,000 Boilers.	15,000	800,000	80,000
3	Losh, Wilson, & Bell	Walker	1807	Millwork, Steam Engines for Mills, Blast Furnaces, and Colliery purposes............	250	250 Stationary Engines and extensive Foundry Work ..	9000	......	......	87,500
4	R. & W. Hawthorn	Newcastle	1817	Millwork and general Machinery, Waterworks, Mill, Colliery, Marine, and Locomotive Engines.............	984	797 Locomotive Engines, 121 Mining do., 9 pairs and 2 single Waterwork do., 171 general do., and 30 pairs and 20 single Marine Engines	15,000 excusive of Locomotives.	......	......	147,800
5	R. Stephenson & Co.*	Newcastle	1823	Locomotive, Marine, and Mill Engines, Bridges, &c..........	1500	1510 Locomotive Engines, 115 Marine Engines, 203 Marine Boilers, 268 Stationary Engines and Boilers ..	85,000 Engines and Boilers, exclusive of Locomotives.	80,000	2,000,000	225,000
6	Marshall & Co.	Willington Quay ..	1830	Side-lever Paddle Engines for Tug Steamers, and inverted direct acting Engines for Screw Engines	300 in Engine Shops, 700 in Boiler Shipyard	600 Engines, with a proportion of Boilers for the same, chiefly for Steamers........	8000	......	......	150,000

* 38 Wrought Iron Bridges, of various sizes and descriptions.

TABLE A.—*Continued.*

Number.	Manufacturers. Name.	Manufacturers. Address.	Date of establishment of Works.	Description of Work executed.	Total number of hands employed.	Total number of Engines, Boilers, Machines, or Mills, completed since the commencement of their works.	Horse-power of said Engines and Boilers.	Quantity of Raw Materials used in the construction of the said Engines and Machinery.	Approximate value of Raw Materials.	Estimated value of Work turned out per Annum.
								Tons.	£	£
7	Richardson & Sons	Hartlepool	1838	Marine Engines and Machinery connected therewith....	600	840 Steam Engines and Boilers	12,518	20,000	800,000	90,000
8	Gilkes, Wilson, & Co	Middlesbro'........	1844	Millwork and general Machinery, Mill, Colliery, Marine and Locomotive Engines, Bridges, &c..................	1000	100 Locomotive Engines, and a large number of Blowing Engines, Steam Cranes, Marine and Stationary Engines	......	......	......	150,000
9	W. G. Armstrong & Co.	Elswick............	1847	Millwork and general Machinery, Mill, Waterworks, Locomotive and Hydraulic Engines, Bridges, &c.	800	202 Locomotive, Stationary, Pumping, and Dredging Engines, 265 Boilers 178 Hydraulic Engines, 150 Accumulators	15,000 Steam Engines. 1400 Hydraulic Engines.	......	1,200,000	120,000
..	Do.	Do.	....	Guns and Ammunition.........	3000	....	......	......	......	500,000
10	J. Renoldson	South Shields......	1847	Marine Engines for towing purposes	40	4 Stationary Engines, 66 Marine Engines for towing purposes	2250	Cast Iron 684, Forged do. 255, Copper 21, Brass 48, Boiler Plts. 726, Bar Iron 396.	......	6,000
11	Palmer Brothers & Co. ..	Jarrow	1852	Marine Engines and Machinery connected therewith....	600	71 pairs Marine Engines. 120 Boilers	11,842	Cast Iron 6000, Forged do. 2500, Boiler Pl. 2000, Copper & Brass 350.	450,000	90,000
12	Morrison & Co..............	Newcastle	1853	Millwork and general Machinery, Mill, Waterwork, Colliery and Marine Engines, Steam Hammers, &c.........	600	80 pairs Marine Engines, 170 Boilers, 90 Steam Hammers, 30 Land Engines, 66 Steam Cranes	5824	3460 used in the construction of Marine Engines and Boilers.	159,720	90,000
13	Thompson & Co	Newcastle	1856	Millwork and general Machinery, Mill and Marine Engines, &c........................	400	26 Land Engines, 7 Dredging Machines, 12 Sugar Mills, 65 pairs Marine Engines, 200 Steam Cranes, 16 Cotton Presses..........	4645	......	160,000	60,000
14	Joy & Co..................	Middlesbro'	1862	Steam Engines and Patent Steam Hammers	50	1 Engine, 4 Boilers, 13 Patent Hammers	45 Steam Engines.	......	......	7,500

TABLE B.—SHOWING THE AVERAGE NUMBER OF MEN EMPLOYED BY MESSRS. R. AND W. HAWTHORN, FROM THE COMMENCEMENT OF THEIR WORKS IN 1817 TO THE YEAR 1862.

Years.	Average Men.	Years.	Average Men.
1817	8 to 10	1838 to 1842	511
1818 to 1822	42	1843 to 1847	726
1823 to 1827	108	1848 to 1852	907
1828 to 1832	216	1853 to 1857	890
1833 to 1837	318	1858 to 1862	984

TABLE C.—STATISTICS HAVING REFERENCE TO THE INTRODUCTION OF STEAM POWER FOR TOWING PURPOSES ON THE TYNE.

Date.	Name of Steamer.	Horse Power.	Engine Builders.	Total number employed in the United Kingdom.
1814	Perseverance	8	Crowther	17
1815	Swift	3		21
1816	Eagle	20	Watt	31
1817	Enterprise	5	Robson	40
1818	Speedwell	10	Robson	52
1819	Hope	6	Robson	64
„	Swift	8	Robson	85
1820	Tyne	10	Robson	78
„	Two Brothers	9	Robson	79
„	Indefatigable	8	Hawthorn	80
„	Duchess of Northumberland	10	Hawthorn	81
1821	Navigator	18	Hawthorn	117
„	Safety	14	Hawks	118
„	Union	4	Gibson	119
1822	Lemington Packet	7	Hawthorn	148

APPENDICES.

THREE-POWERED HYDRAULIC ENGINE.

BY

SIR WILLIAM G. ARMSTRONG AND CO.

The object attained by the principles of construction of this engine is economy in the motive power. This is effected by proportioning, in a measure, the quantity of water used for producing motion to the amount of work to be done.

The cylinders of this engine being fitted with rams and pistons, have, consequently, differential areas on either sides of the pistons—the areas being usually in the proportion of 2 to 1.

By an arrangement of double slides, the water pressure can be conducted to either the smaller or larger areas alone, or to both combined, leaving always the opposite side of the piston acted upon by the pressure freely open to the exhaust.

Thus, when the water pressure is let on to the smaller areas in the cylinder alone, the lowest power is obtained; when on to the larger areas alone, the medium power; or when with reciprocating action, on to both the smaller and larger areas, the highest power of the engine is produced.

REPORT ON THE

CONSTRUCTION OF WROUGHT-IRON RIFLED FIELD GUNS, ADAPTED FOR ELONGATED PROJECTILES.

BY

SIR W. G. ARMSTRONG, C.B., LL.D., F.R.S.

In the month of December, 1854, my friend Mr. Rendel, the well-known engineer, submitted to Sir James Graham a communication he had received from me, suggesting the expediency of enlarging the ordinary rifle to the standard of a field gun, and using elongated projectiles of lead instead of balls of cast iron.

This communication was handed by Sir James Graham to the Duke of Newcastle, then Minister for War, with whom I had an interview on the subject, in company with Mr. Rendel.

At this interview I was authorised by his Grace to carry my views into effect, by constructing upon the plan I had suggested one or more guns, not exceeding six in number, and to make the necessary experiments in connection with the subject.

In acting upon the authority thus received, I deemed it expedient to confine myself, in the first instance, to the production of a single gun, but to make that one gun the test not only of the principles I had recommended, but also of the feasibility of loading field pieces at the breach, and applying certain mechanical arrangements to counteract recoil, and facilitate the pointing of the gun.

The substitution of elongated solid projectiles for spherical bullets is an essential step to the attainment of very extended range in artillery practice; but the lengthening of a solid projectile involves the necessity of strengthening the gun to enable it to resist the greater intensity of force which becomes necessary to give the required velocity; and this object can only be effected, consistently with lightness, by constructing the gun of steel or wrought iron, instead of cast iron or bronze.

The tensile strength of these several materials is exhibited in the following table:—

	Breaking strain per square inch of section.
Cast steel, about	60 tons.
Shear steel	42 "
Wrought iron	26 "
Bronze, or gun metal, about	16 "
Cast iron	8 "

The first and strongest of these substances—viz., cast steel, may be set out of the question, as it appears impracticable, in the present state of manufacture, to produce it in masses sufficiently large without the occurrence of flaws which, in the great majority of cases, would destroy its efficiency. Shear steel may be forged, like wrought iron, into large pieces; but in a gun made from a solid mass of either of these substances, the full strength of the material can never be realised, because the tenacity of wrought iron, or steel, is always less in the lateral than in the longitudinal direction; and it is the lateral strength which in a gun so manufactured would be chiefly brought into action. There is also much uncertainty in the lateral strength of wrought iron or steel, because the flaws or imperfections of welding which exist in all thick masses of those materials almost invariably run in the direction of the length, and in general, therefore, only detract from the strength in the transverse direction. It is for these reasons that the barrels of muskets and sporting guns are formed by twisting long slips of iron into spiral tubes, and then welding together the edges, by which means the longitudinal strength of the slip becomes opposed to the explosive force of the powder, and the weldings being transverse with the bore, have no important influence in lessening the strength of the barrel.

It is also to be observed, in reference to the strength of steel or wrought-iron cannon, that the resistance of a cylinder to internal pressure does not increase in the ratio of its thickness. If the cylinder be regarded as made up of a number of

concentric layers, each capable of sustaining, without injury, a degree of extension proportionate to its length, it is obvious that the greater the circumference of each layer, the less will it be stretched by a given distention of the bore, and, consequently, the less will it contribute to the general strength of the cylinder. The ratio of this decrease is very rapid, being as the square of the circumference, or distance from the centre inversely; and, consequently, when the cylinder is thick, the deficiency of strength from this cause becomes very great.

Now this defect can only be remedied by giving to the external portion of the cylinder a certain initial tension, gradually decreasing, and finally passing into compression towards the centre; and although this condition cannot be effected by any known process of forging or casting, yet where wrought iron or steel is the material used, it may in a great measure be attained by shrinking an outer cylinder upon an inner one, and in like manner superadding others until the requisite thickness has been acquired.

The method, however, of forming steel or wrought-iron guns, by simply forging the material into the required form, and boring it in the usual manner, was so much recommended by its facility, that I was induced to make some experiments to test its sufficiency.

With this view a number of cylinders were forged, each 12 inches long, and 5 inches in the outward diameter. These were bored to an internal diameter of 1$\frac{5}{8}$ inches, and tested in the following manner:—Each cylinder was entirely filled with gunpowder, and the open end was pressed by screws against a very thick iron tube bored to the same diameter, and containing a cylindrical shot of lead equal in weight to about three spherical shot of the same diameter and material. Several of the cylinders burst on the first discharge, and those which remained uninjured were afterwards reduced in thickness, and tested a second time. If they still resisted the explosion, the thickness was further diminished, and this mode of proceeding was continued until fracture took place in all of them.

The results obtained in this manner showed, as had been apprehended, great uncertainty in the strength of the material, and rendered it impossible to define the thickness necessary to resist a given charge of powder. I felt compelled, therefore, to dismiss this mode of construction, and to adopt another more correct in principle, but more difficult of execution.

In the above experiment, it was found that steel was more subject to defects of welding than iron; but being a harder substance, and therefore more fitted to form the surface of the bore, I determined to apply it as an internal lining, and to obtain the necessary strength by encircling it with twisted cylinders of wrought iron, tightly contracted upon the steel core by the usual process of cooling after previous expansion by heat. Considerable difficulties were encountered in carrying this plan into practice; but I ultimately succeeded in completing a gun, of which the following is a description.

The gun, when fired, recoils upon an ascending slide without displacing the carriage, and then returns to its place by gravity. The slide-frame turns upon a pivot which permits the gun to be pointed to either side without moving the carriage. The gun is elevated and depressed by means of a screw, which is fixed to and moves with the slide, and a similar screw is applied for the traversing or horizontal movement.

The arrangement for loading at the breech may be described as follows:—At the back end of the gun a powerful screw is applied, having a hole through the centre, forming a prolongation of the bore, and through which hole the bullet and charge are delivered into the gun. A "breech-piece," with a mitred face, fitting a similar face at the end of the bore, is then dropped into a recess, and by the action of the screw pressed tightly into its seat, so as effectually to close the bore.

In order to facilitate the loading, the bullet and cartridge are placed in a tube, from which they are thrust into the gun by means of a rammer.

The breech-piece contains the vent, with a cavity for receiving a small quantity of powder to ignite the charge; and as the breech-piece is prepared for firing while the gun is being loaded, no time is lost in subsequent priming.

Several of these breech-pieces accompany the gun, some being arranged to fire by percussion-caps, and others by friction-tubes or port-fires.

The bore of the gun is 1¾ inches in diameter, and contains eight spiral grooves having an inclination equal to one turn in 12 feet. These grooves terminate at a distance of 14 inches from the breech, and the bore then gradually expands, in a length of 3 inches, from 1¾ inches to 1⅞ inches in diameter. The bullet, in the operation of loading, passes freely through this widened space; but its diameter being a little in excess of the bore, it lodges in the tapered contraction at the commencement of the grooves.

The mode in which the gun is made up of separate parts consists in surrounding the steel centre with twisted cylinders of wrought iron, made in a similar manner to gun barrels, and, being shrunk upon the steel, they are in that state of initial tension which is necessary to bring their entire strength into operation.

The weight of the gun by itself is about 5 cwts.; but, including the carriage, its weight is nearly identical with that of a light 6-pounder, with its carriage complete. It is probably heavier than necessary, but recoil might be inconveniently increased if the weight were much reduced.

Having now described the gun and its carriage, I shall proceed to speak of the projectile.

The resistance which a projectile encounters in passing through the air is mainly dependent upon the area of its cross section, and the advantage of lengthening a bullet consists in augmenting the weight without increasing this sectional area; but in order to realise this advantage, it is essential that the bullet be guided endways in its course, and this can only be effected by causing it to rotate rapidly upon its longer axis, which is accomplished by firing it from a rifled bore.

This peculiar influence of rotation, in giving persistency of direction to the axis of a projectile, is entirely distinct from that which it also possesses of correcting the tendency to aberration arising from irregular form or density; and in order to investigate experimentally the nature of this action, I constructed an apparatus by which a cylindrical bullet could be put into extremely rapid rotation, and be then suspended in a manner which left it free to turn in any direction.

When thus suspended, the rotating bullet exhibited the same remarkable properties as are possessed by the revolving disc in the recently-invented instrument called the "Gyroscope." When pressure was applied to either end of the axis, the movement which took place was not in the direction of the pressure, but at right angles to it. Thus a vertical pressure deflected the axis horizontally, while

lateral pressure deflected it vertically. But the important point elicited was this, that the time required to produce these indirect movements became greater as the velocity was increased, and, consequently, that the amount of deflection produced in a given time by a given pressure, diminished as the rotation was accelerated. Now, all disturbing forces which operate upon a projectile during its flight, must necessarily be of very short continuance, and can therefore have but little influence in diverting the axis when thus stiffened by rapid rotation.

I also found that a cylindrical bullet with tapered extremities, was more easily deflected than one of equal weight, with flat, or merely rounded ends, because the mean diameter of the bullet, and consequently the mean velocity of rotation, were thereby diminished. So far, therefore, as accuracy of flight depends upon rigidity of the axis, it would appear that the nearest practicable approach to a plain cylinder is the most desirable form for a projectile; but there are other considerations which modify this conclusion.

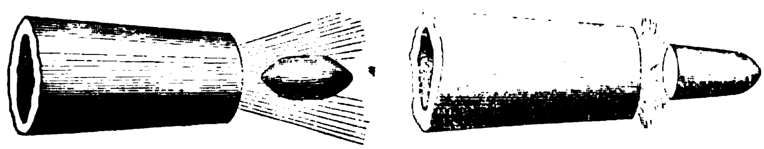
It is also to be observed, that since the rigidity of the axis (relatively to the magnitude of the projectile) depends upon the mean velocity of rotation, the inclination of the spiral grooves in a rifled gun should vary inversely with the diameter of the bore. Thus, if one turn in 8 feet be assumed as sufficient for a rifled bore of 1 inch in diameter, one turn in 48 feet should be sufficient for a bore of 6 inches, provided the same form of projectile be used.

The forms of bullet which I actually tried with the gun were exceedingly numerous, and the material used for these bullets was in all cases lead hardened by an intermixture of antimony and tin; and the weight varied from 2 lbs. to 3½ lbs.

In trying these various bullets, a number of each kind was fired against a vertical bank at a distance of 435 yards. The gun was constantly pointed at the same object, and the closeness of the bullet-holes to each other was taken as the criterion of accuracy, while the drop below the level of the aim furnished an indication of comparative range.

The conclusions arrived at from these and other experiments may be concisely stated as follow :—

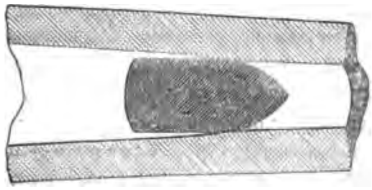
1st.—A pointed form at the front end of the bullet is unfavourable to accuracy of flight, unless the cylindrical part of the bullet be of considerable length; but, on the other hand, a pointed, or conoidal form behind, has the effect of increas-



ing the accuracy attained. This may be explained upon the very probable supposition that the blast from the mouth of the gun, impinging upon the rear of the bullet, will operate more unfavourably upon a flat or hollow end, than upon a rounded or conical one—a difference which I have endeavoured to illustrate by the subjoined sketch.

2nd.—Increase of length, in the cylindrical part of a bullet, always increases precision; but, when carried beyond a certain limit, lessens the initial velocity, even where the charge is proportionately augmented.

3rd.—Both range and accuracy were effected in an important degree by the manner in which the bullet fitted the contraction in the gun. When the fitting part was in front of the bullet, the pressure of the gas operating upon its sides, compressed it in the manner represented below; and the same effect was produced, though in a less degree, when the conical, or rounded end at the back, projected too far into the powder-chamber.



Deformed bullet caused by lateral compression.

These effects were rendered apparent by inspection of bullets recovered after firing, many of which were found in nearly the precise condition in which they quitted the gun.

The bullet ultimately selected is a little longer and heavier than that shown in the preceding diagram, and differs from the pointed bullet, in being longer in the cylindrical part, and having a coned, instead of a rounded, end behind; and although its drop in a range of 435 yards is considerably more than that of several of the shorter bullets, yet there is little doubt it will excel them in range at higher elevations of the gun; because I have found that a pointed front only operates in sustaining the flight of the bullet when the range is long; and a high initial velocity, which materially lessons the drop in short distances, does not produce the same effect, in a corresponding degree, when the distance is increased.

Great improvements were effected in the accuracy of the firing by modifying the shape of the projectile; but although the experiments were very protracted, I feel that they require to be further prolonged in order to arrive at the greatest attainable perfection in the form of the bullet.

The ranges at different elevations were not ascertained with the form of bullet ultimately adopted; but with a 3 lb. pointed bullet, and charges of 12 oz. of powder, they were as follows :—

RANGES WITH THE RIFLED GUN AND 3LB. BULLETS.

Elevation.	Range in Yards.	
½°	408	Measured to first graze upon a plane about 5 feet below the centre of the gun.
1°	770	
2°	1,112	
3°	1,500	
4°	1,840	
5°	2,056	
6°	2,300	
7°	2,600	

The powder used was a mixture of blasting and "double seal" powder in equal proportions. The distances given are in most cases averages of several shots; but, in some instances, they were only approximately determined. When the gun had

more elevation than 7°, the bullets could only be fired out to sea, and the range could not be ascertained.

By way of comparison with these results, an extract is here given from the last edition of Sir H. Douglas's Naval Gunnery, specifying the ranges obtained with a 68-pounder throwing shot with full charges, which ranges, it will be seen, are, upon the whole, no greater than those of the 3 lb. bullet fired from the rifle gun.

RANGES WITH A 68-POUNDER.

Elevation.	Range in Yards.
¼°	340
1°	833
2°	1247
3°	1558
4°	1737
5°	2085
6°	2307
7°	2440

In trying the initial velocity of the shot by means of a ballistic pendulum, I was enabled to observe its penetrating power. When fired with charges of 13 oz. of powder, a 3 lb. bullet passed through 2 feet 2 inches of hard elm timber, and flattened against a cast-iron block forming the back of the pendulum. The initial velocity was similar to that generally obtained with round shot fired with proportionate charges—viz., about 1550 feet per second.

In the course of the experiments made with the gun, upwards of 500 rounds were fired; and ample opportunity was thus afforded of judging as to the durability of the parts affected by the loading at the breech. At first the fitting surfaces which closed the bore were of unhardened steel; but these soon failed, being cut away in numerous small channels by the ignited gases. The steel was then hardened; but instead of being rendered more durable, it yielded to the action of the powder more rapidly than before. Conceiving, therefore, that the erosion was not a mechanical action, but a chemical effect of combustion; and that a metal which was a better conductor of heat than steel or iron would be less liable to burn on the surface, I was led to substitute copper as the material of the parts affected, and no further difficulty was experienced. The copper fittings applied for this purpose consists of two annular pieces, one of which is screwed into the breech end of the gun, and the other fixed upon the breech-piece. These fittings can very easily and quickly be repaired, when necessary, by means of a tool provided for that purpose, and can also be removed and replaced by others kept in readiness for use; and there is nothing to prevent these operations being performed by the gunners when on service, if they be previously instructed.

The advantages of loading at the breech may be stated as follow:—

1st.—It permits of a bullet being used of a larger diameter than the bore, by which means accuracy of fit is secured, and the material of the bullet is forced into the grooves of the bore.

2nd.—Any ignited matter remaining in the gun after firing may with ease and certainty be removed, or, if left in the gun, it will be thrust forward from the part where its presence would be dangerous, by the insertion of the succeeding bullet.

3rd.—In the arrangement which I have adopted, the perishable part of the gun, viz., the vent and its vicinity, is comprised in the moveable breech-piece, which may be easily replaced when worn or otherwise injured.

4th.—A rifled gun, loaded at the breech, may be more rapidly fired than a rifled gun loaded at the muzzle, because the fouling of the bore presents no impediment to the insertion of the bullet when introduced from behind; but as compared with smooth-bored ordnance of the ordinary description, there is probably nothing to gain in point of quickness of firing.

The gun was remarkably free from tendency to become heated by firing, a fact which can only be explained upon the supposition that the heating of a cannon is occasioned, not by the contact of the flame, but by some molecular action of the metal, produced by the explosion, and more effectually resisted by wrought iron than by cast iron or bronze; but possibly the compound structure of this gun may also operate to deaden vibration, and prevent the evil in question.

It may, perhaps, be objected to this gun, that, from the smallness of the bore, it cannot be applied for throwing shells as well as solid projectiles; but the fact is, these two purposes are incompatible with each other unless both be imperfectly attained, for while the one necessarily requires a large bore, the other demands a small one; and it therefore seems preferable to have separate guns specially adapted for each application. As a civilian, I speak with diffidence upon the advantages which I believe the long range of this description of field gun will afford in its military application; but I may be permitted to observe, that the incident which chiefly contributed to direct my attention to this subject still appears to furnish a forcible illustration of its importance. I allude to the memorable service rendered at Inkermann, by means of two 18-pounders, laboriously dragged from the batteries, and ultimately directed with great gallantry and success against the Russian Artillery, at a distance from which the numerous but lighter guns of the enemy could not effectually reply. Now, these two battery guns were but a clumsy substitute for light long range guns, which would have rendered the same important service with more promptitude and ease, and could have operated at a greater distance from the enemy's fire. It is, perhaps, chiefly as "guns of position," commanding important points at great but ascertained distances, that these rifled guns would be valuable, because long range can only be made available where distance can be determined, which it cannot easily be in the rapid operations for which "field pieces" are employed. It is, therefore, as adjuncts to, and not as substitutes for, the present descriptions of field ordnance that I propose the adoption of these guns; and when fully brought to perfection, I believe they will furnish a most important addition to the artillery of an army.

With respect to the construction of heavy ordnance by the process of twisting wrought iron bars into cylinders, and combining them in the manner described, there appears to be no great difficulty in so doing if proper apparatus be provided for the purpose. It would not, however, be advisable (except in peculiar cases) to apply the principle of loading at the breech except to guns of small dimensions, because in heavy ordnance the moveable parts would become too cumbrous to be conveniently handled.

ELECTRIC LEAKAGE GUAGE.

FIG. 3.

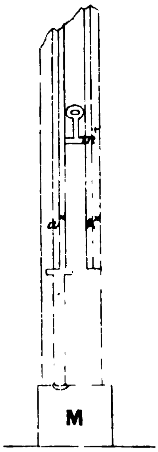
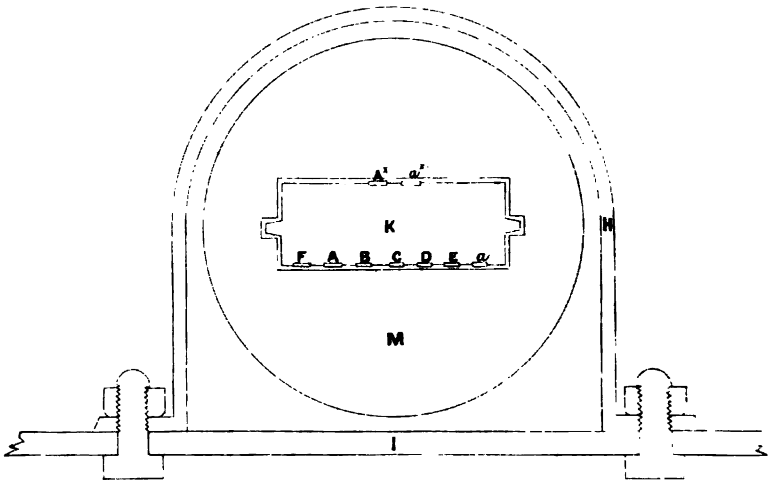


FIG. 1.



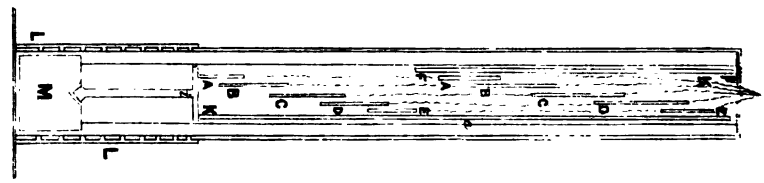
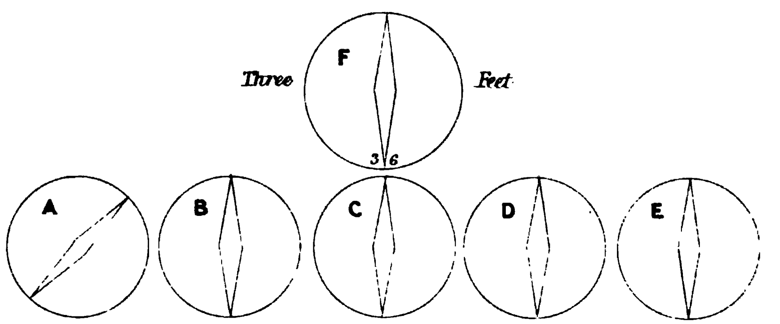


FIG. 2.

FIG. 4.

	In.	In.	Feet	In.	In.	Feet	in.	in.	Feet
Frm. F 3 feet to	4	8	4	4	8	5	4	8	6



Frm. 6 Inches to 9 12 15 18 21 24 27 30 33 Inches.

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THE ELECTRIC LEAKAGE GAUGE AND ELECTRIC SEA PLUMMET.

BY

D. B. WHITE, M.D.

[*These instruments are worked by the most simple electric apparatus, such as may be used on shipboard, requiring slight knowledge and little care and attention.*]

THE ELECTRIC LEAKAGE GAUGE.

The Leakage Gauge consists of a metal tube, say of six inches internal diameter, perforated at its lower part, and surrounded there with wire gauze. In an iron ship, as in the plan, it is attached to the bulk-head in the principal hold ; in a wooden one, it is placed beside the pumps, but both cases in the well. Within this tube is fixed a rod of wood, on which slides easily up and down a float of copper or other suitable material. On this rod, at certain intervals, is placed a series of conducting plates connected, by separate wires, with one pole of the battery. On the float is a connecting plate or tongue connected with the other pole. Both class of wires unite into a line, and pass on to the battery ; one set through the index. As the float rises, its tongue gliding over the plates upon the rod completes the several circuits, and deflects the needles accordingly. By means of a simple arrangement, explained in the description of the Sea Plummet, these six circuits give nineteen indications, and the first series being of three inches, and the second four, makes 66 inches, which, with the six before the float will rise, constitutes the index—six feet—enough for every practicable purpose. An alarm is also appended to the apparatus. When the leakage rises to a certain height, determined on beforehand by the circumstances of the ship, &c., a tongue upon the float presses on the sliding plate or rod, making thus the circuit, and setting on a bell. The leakage index may be placed before the steersman, and the bell rung into the captain's cabin or other suitable situation. As four circuits may be formed at once, two small batteries may be used. It has been thought that the usual leakage water being salt, the plates without the float might serve the purpose, and further that any needle connected with a plate beneath the water would be more or less deflected. Practically, however, with small batteries this is not the case, the needles being but slightly influenced when the circuit is not completed by a metallic conductor. The apparatus may be so arranged, however, that the conducting plate *a*, upon the rod fig. 1 and fig. 2, may be omitted there, the wire being connected with tongue *i* on float fig. 2, or the conducting plates A, B, C, D, E, F, may be raised above the leakage altogether, the tongue being carried up to reach them. The arrangement here adopted is, however, found the simplest and the best. One of the advantages of such an instrument is, that you have before you, at all times, the absolute leakage of the ship. Casualities occasionally happen on shipboard, in the intervals of sounding, only giving indications that may escape attention, and thus lead to most disastrous results.

DESCRIPTION OF THE PLATES.

Fig. 1. Horizontal section of the tube H, attached to bulk-head I, with float M and rod K; A, B, C, D, E, F plates connected with the wires that pass around the needles to one pole of the battery; *a* the one that goes direct to the other pole; $A^{\times}$ $a^{\times}$ the plates for action on the bell.

Fig. 2. Vertical section of tube; *i* insulated connecting tongue; L lower part of tube perforated with wire gauze covering; the other letters refer to the same as in fig. 1.

Fig. 3. Elevation of back of wooden rod. The arrangement for the ringing of the alarm:—$i^{\times}$ connecting tongue on float; $m^{\times}$ moveable plate fixed at the height required.

Fig. 4. The Index, showing that the leakage stands from six to nine inches. The numbers below the needles indicate by intervals of three inches to three feet; the numbers above by intervals of four inches from that to six feet. The numbers opposite the needles indicate the deflection of that needle alone; those between, the deflection of the needles adjoining.

THE ELECTRIC SEA PLUMMET.

The Electric Sea Plummet can be dropped into the sea at any time to any depth within its range of line, and kept there, however quick the passage of the vessel or strong the current, indicating on board the perpendicular depth, and ringing an alarm should ground be reached within that range.

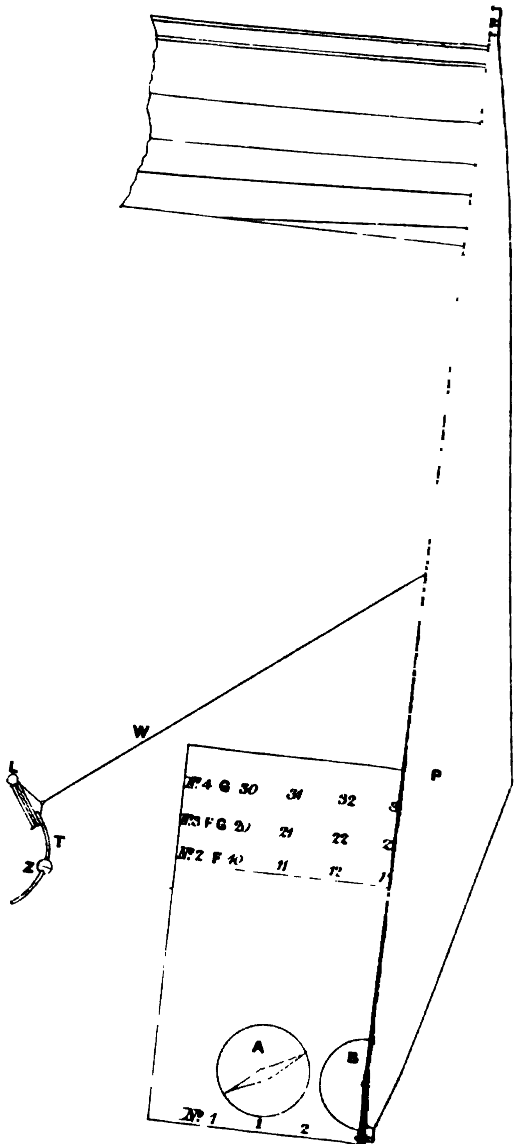
This plummet is in fact a cylinder, fitted with an air and water-tight piston acting against a powerful spring. As it descends, the water presses on the piston, which carries tongues in connection with one pole of the battery, by wires running along the line. In the cylinder are insulated plates, communicating also through the line with the other pole; these various wires forming helices around their respective needles in their course. To the lower end of the plummet is attached a feeler, or strong flexible rod, covered with a case of Indian-rubber; towards its extremity is enclosed a cup, made of non-conducting material, and containing mercury. To this cup, and communicating with the battery along the line, runs two wires—a positive and negative—the one connected with the upper part of the cup, the other with the mercury. At right angles to the plummet projects two plates, or wings of brass. The indications are by deflected needles, acted on by the electric current.

DESCRIPTION OF THE PLATES.

Fig. 1 shows the plummet as hung out from the bowsprit on approaching land.

Fig. 2 shows a section of the cylinder N, and the piston M, and wings P, the spring omitted to show the plates A, B, C, D, E with F, G. The piston is kept tight by Indian-rubber rings *d d*, *d d*, and leather cup H H; *a b* are tongues and wires connected with the piston.

Fig. 3. A cross section of the same; R, a segment of the cylinder, carrying the cylinder plates, carefully insulated, and firmly bolted in by the cap, T, over the Indian-rubber S.



A Reid Newcastle

Fig. 4 shows the plummet in an angle it might take, with the spring carefully wrapped for insulation, the feeler broken for saving space; Z, the cup. At X, the seven wires pass to the cylinder plates; and at *y*, the two into the piston. Two more are continued along the feeler. W W W, the line containing the wires. V, cord attached to plummet to give the angle necessary for its descent.

Fig. 5. The Index to 40 fathoms.

ACTION OF THE APPARATUS.

When the plummet is dropped into the sea either from the bowsprit, as on the plan, or elsewhere, from the formation of the wings, and the mode of the connection with the line, when the current from the passage of the ship presses, the instrument takes such an angle (fig. 4) that a portion of the force in action presses it down as the air current forces up the kite. It is strange that, notwithstanding the importance of sinking the plummet under all circumstances, no mode of effecting this has ever been devised, but that by simple gravity. To give the indications to the ship, the action is as follows :—There are upon the cylinder, fig. 2, seven insulated conducting plates, five A, B, C, D, E the units, F G the tens. There are four series of the Unit plates exposed at intervals to the action of the piston tongue *b*, but each on the same circuit connected together underneath, as shown by the dotted lines. When first immersed the tongue presses on plate A above series 1, as shown upon the plan, and deflects the needle A as in the index, fig. 5, marking 1; it then passes on to A B, together 2; B above 3; B C, together 4, and so on to E above 9. The tongue *a* now passes on to plate F above 10, and this with the second series extends to 19. It then takes up F G 20 with the third series 29, and afterwards G alone, with the fourth series making the 39 to 40 fathoms—the full scope of this instrument, and deemed enough for all the purposes intended. Should it be required, with three additional plates, say H I J, and three additional wires, with the needles, the index would extend to 100 fathoms. After the elucidation in the leakage gauge, and the incidental observations made, all further explanation of the index, fig. 5, seems superfluous. To indicate the plummet at 28 fathoms the needles deflected would be F G, with D E, for 38 G with D E. To give the alarm, when the feeler and the plummet fall upon the ground, the mercury in the cup flows so as to connect the two wires running to it, and rings a bell that may be placed in the captain's cabin or elsewhere. The indexes may be hung; and it may be stated that no pitching nor rolling of the vessel will give the slightest motion to the deflected needle. The feeler also, by its flexibility, elasticity, and resistance to all friction, is a safeguard to the plummet when it touches ground. The instrument may be made so that the piston being hollow the spring V, fig. 4, may reach the entire length, and be compressed within the piston as it passes inwards. A hollow copper ball, L, fig 1, may be screwed to the upper part of the cylinder; or under certain circumstances a few of them, connected by a chain may be useful in giving to the plummet the required position. As five circuits may be with the bell at once in action, two batteries are required. The advantages assumed for this plummet are the certain indication as to the absolute perpendicular depth at which it hangs, and the knowledge of this fact during the most rapid passage

without pulling up the ship to take a sounding. To indicate the danger of such pulling up, and to show the impossibility of effecting this operation without doing so by any means hitherto in use, it may be stated that when, some time ago, a captain of the Cunard Line ran his ship on shore whilst proceeding at a rapid rate, his brother captains offered an exculpation in a letter to the Times, alleging as a plea that to lie to under the circumstances would have been as dangerous as to proceed. I feel bound to express the obligations due to my assistant, Mr. Donaldson, for his numerous experiments and suggestions relative to this and to the Leakage Gauge.

ON

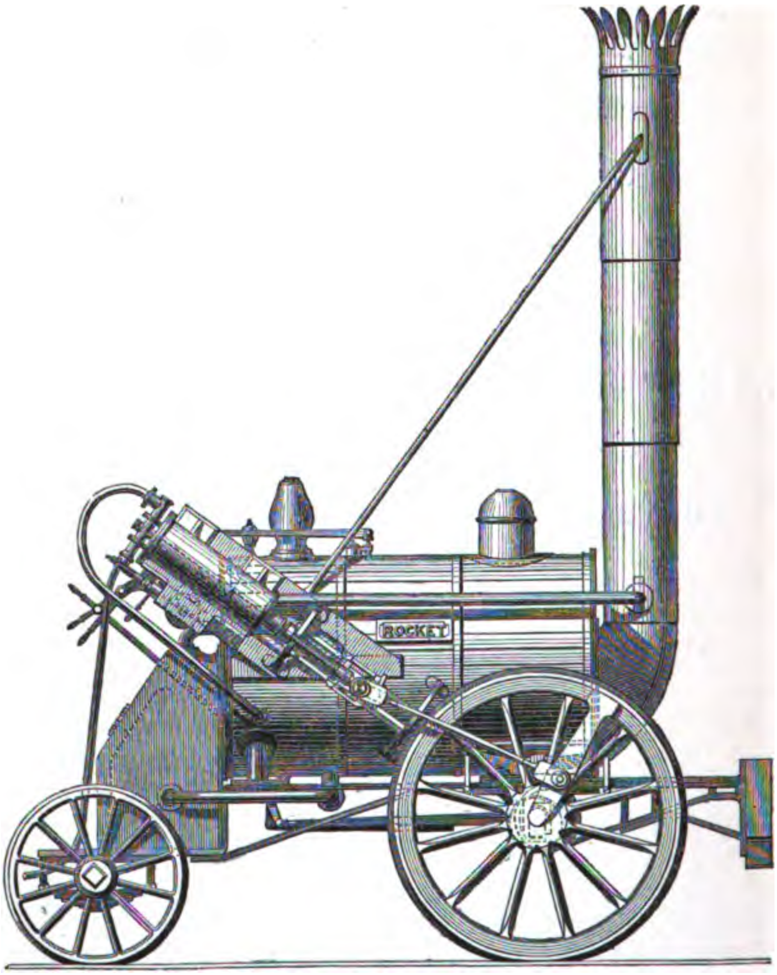
THE RAILWAYS AND LOCOMOTIVES

OF THE DISTRICTS ADJOINING

THE RIVERS TYNE, WEAR, AND TEES.

BY

JOHN F. TONE, C.E.



Stephenson's "Rocket."

ON

THE RAILWAYS AND LOCOMOTIVES

OF THE DISTRICTS ADJOINING

THE RIVERS TYNE, WEAR, AND TEES.

THE district comprised within the boundaries of the Northern Coal-field has been the seat of mining operations for the supply of the Metropolis and the South of England from a period very remote, as compared with the general opening out of the coal-fields of Wales and Derbyshire; and long ere the canals, which were formed to connect the Midland Coal-fields with their respective markets, were constructed, the produce of this coal-field was brought on tramroads to the Tyne and there shipped.

Owing to the physical configuration of the coal-fields of Northumberland and Durham, the mines were situated for the most part at considerable altitudes above the river Tyne, being placed, as it were, on the sides of the valley, thereby rendering the introduction and use of the canal system a matter of so much difficulty that, notwithstanding its general adaptability to the cheap conveyance of heavy loads, the produce of our northern coal mines continued to be led to the banks of the river on these tramroads, long after the general introduction of the canal system elsewhere.

The history of the progress of the railway system, like that of other great mechanical improvements, is a record of difficulties encountered acting as a spur to invention, and eventually resulting in successful improvement; and it may fairly be said that, to the necessities of the Newcastle coal trade the world is indebted for its railways.

The early tramroads seldom exceeded two or three miles in length; they were in use about 260 years ago, and were constructed mostly of oak and beech timber; and of this last, extensive woods are in existence

in the upper portion of the county of Northumberland, planted apparently about 120 years ago, up to which period the demand for timber for these tramroads had not entirely ceased.

Wooden tramroads were in general use till about 1780, although cast iron rails were first used about 1770, but up to this time the use of cast iron rails still continues in some of the older private railways; these, however, are now almost always replaced with wrought iron as they are worn out, and may soon become matters of history.

The conversion of the wooden tramroads into iron ones was the first great step in the improvement of railways, which (after the introduction of wrought iron rails in 1820) assumed their present shape, as far as the general principles of construction were concerned.

An inspection of the map which accompanies this paper, will show the great extent to which the railway system has been carried in these districts.

The private railways are marked thereon by blue lines; the public railways, whose termini are within the districts, are marked by continuous red lines; and the through lines, constructed for more general purposes, with dotted red lines. So completely has the country been intersected with railways, private and public, that, on an area of about 666 square miles, comprised in the Northern Coal-field, there are only 122 square miles, or about one-fifth of the whole at a greater distance than one mile, and only 221 square miles, or one third of the whole at a greater distance than half a mile from a railway, public or private.

	Miles.
The total length of the private railways in the entire district is	287
The public railways constructed for the more immediate service of the district, as shown by continuous red lines on the map, and exclusive of main lines, as under, comprise	387
Making together	674

The foregoing mileage of public railways is exclusive of those portions which have been constructed for more general purposes, and which, as before mentioned, have not both of their termini within the district; thus excluding from the calculation the main line from Darlington to Berwick, the Newcastle and Carlisle, South Durham and Lancashire, Border Counties, and Wansbeck Railways.

The complete reticulation of the district, by means of these railways, will be understood from the circumstance that, within the actual limits of the coal-field—itself comprising about 666 square miles—there are

(including all lines general and local) 609 miles of railway, being nearly one mile of railway for each square mile of the surface of the Northern Coal-field, in addition to the 1300 miles of underground railway, as estimated by Messrs. Wood and Taylor in their paper, which has been already read on this occasion.

	Per Ton Per Mile.
Previous to the introduction of tramroads, the old pack horse conveyed 3 cwts. at 3 miles per hour, and travelled on an average about 8 miles with his load. The cost of this mode of conveyence was about 1¼d. per cwt. per mile, or ..	30d.
The introduction of macadamized roads increased the horse load from 3 cwts. to 18 cwts., and, with the same mileage performed, the 30d. was reduced to	8½d.
On the early wooden tramroads a horse averaged a load of 2 tons, further reducing the cost of haulage to	3¾d.
The immediate cost of actual haulage on private railways, exclusive of interest on capital and wagons, as before in cases wherein horses, inclines, and fixed engines are intermixed as circumstances require, and with quantities varying from 80,000 to 160,000 tons per annum, is found to amount to about	·07d.
The cost by leading with a locomotive engine costing 38s. per day (and with a load of 126 tons net on the ordinary local railways of the North of England, and in gradients reaching up to 1 in 100, travelling with a load about 35 miles per day, exclusive also of interest of engine and railway, and of wagons as before), amounts to about	·11d.
And on first-class gradients, and under most favourable circumstances, with loads of 350 tons, a mileage of 60 payable miles at a cost of 48s. per day, this haulage may possibly be reduced to	·03d.

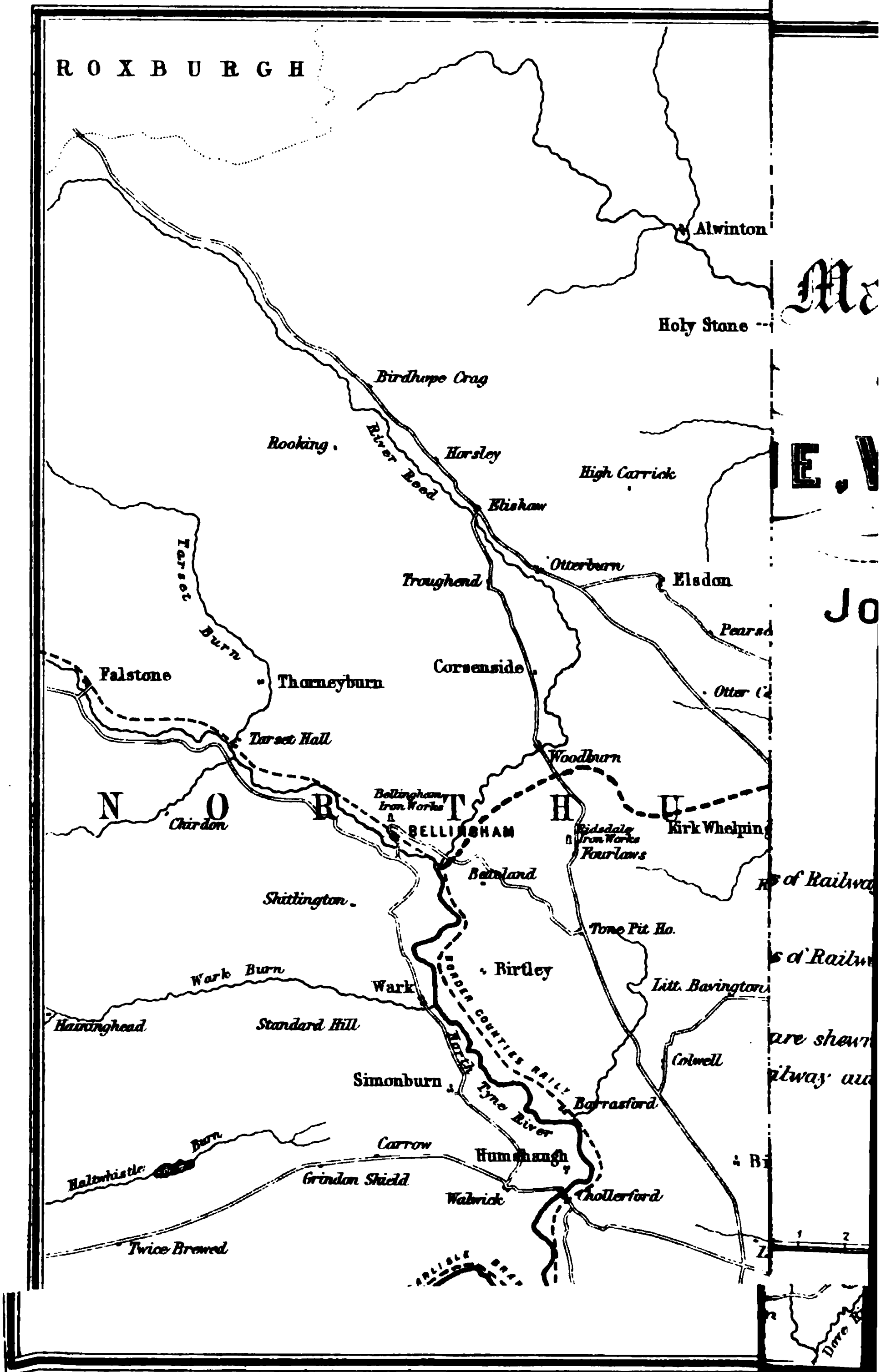
But this can but rarely be maintained in actual working.

Taking even 0·1 of a penny as being the cost of the mechanical effect required to lead a ton of coals on a railway by locomotives, we have reduced the cost to 1-300th part of that by pack horses, and to 1-37th part of the cost of wooden tramroads.

In order, however, more fully to estimate the relative commercial values of the different modes of haulage, as practised in these Northern Coal-fields, it will be necessary to include the other elements of expense, such as interest of capital, maintenance, and the cost of the different

descriptions of railway required in each case, and to compare the entire cost of the locomotive system with that of fixed engines and inclines as practised extensively in these districts.

1st.—By horses, fixed engines, and inclines intermixed, with traffics varying from 80,000 to 160,000 tons per annum, including wagons, maintenance, and renewals (and with interest on cost of line at £1500 per mile), the total expense of leading coals is found to amount to an average of ..	Per Ton Per Mile. 1·1d.
This is exclusive of cost of land or of the way-leaves paid in lieu thereof.	
2nd.—By fixed engines, and inclines without horse power, this expense, including, as before, with a yearly traffic up to 400,000 tons, and a distance up to 7 miles, the total cost amounts to	·54d.
The particulars of this mode of leading are as follows, viz:—	
Engines, inclines, and maintenance of way, in all ..	·43d.
Interest of cost of railways and plant 5 per cent. per annum, rates and contingencies, exclusive of land	·11d.
Making as above	·54d.
By locomotives, and on railways of improved construction, including, as before, this cost, with loads of about 126 tons, and with gradients up to 1 in 100, amounts on an average of railways to	·44d.
as under, viz:—	
The cost of maintaining and working a heavy locomotive engine, including repairs, coke, water, stores, wages, &c., amounts in one year on an average to	£600
To this must be added interest on capital, viz., £2300 at 5 per cent.	115
Making the gross cost of an engine per annum ..	£715
or say £720 per annum.	
But to maintain 3 engines in working order on a railway 4 must be kept, and this reduces the available number of working days to 234 throughout, costing 61s. for every day an engine works on the line, and travelling 35 payable miles with a load of about 120 to 130 tons, gives the locomotive power in conveyance of minerals at the rate of about 12 to 15 miles per hour, the sum of	·17d.



Lithographed by Andw. Reid. Printing Court Buildings, Newcastle on Tyne.

To this must be added the cost of wagons and interest thereon, amounting to .. .. ·125d.

Add interest, maintenance, and renewals of way, rates, &c., on a lead of 800,000 tons per annum, amounting in all to .. ·222d.

Making the cost of leading by locomotive power with full employment .. .. ·517d.

Thus, it will be seen that the locomotive system, although capable of carrying a much greater mineral traffic, is not on the whole more economical than that of fixed engines and inclines as now used in this district, unless in large traffic; indeed, where the traffic does not exceed 400,000 tons, and unless the gradients are better than 1 in 100, the fixed engine has the advantage; with gradients of 1 in 70 the two systems would be about on a par as regards expense. As the gradients improve or deteriorate the locomotive gains or loses respectively, and at a million tons has a superiority.

The history of the rise and progress of the manufacture of the locomotive engines especially connects itself with Newcastle-on-Tyne. The large manufactories of Messrs. Stephenson and Hawthorn have for many years been, and continue to be, of the highest repute.

In 1825, Messrs. Stephenson turned out the first locomotive on the Stockton and Darlington Railway, and in 1829 completed the Rocket.

It is a remarkable circumstance that, notwithstanding the lapse of 34 years, during which the manufacture of locomotives has increased at a rate almost without precedent in similar matters, yet, in the general principles of mechanical construction, the present most improved locomotive remains very closely analogus to the Rocket.

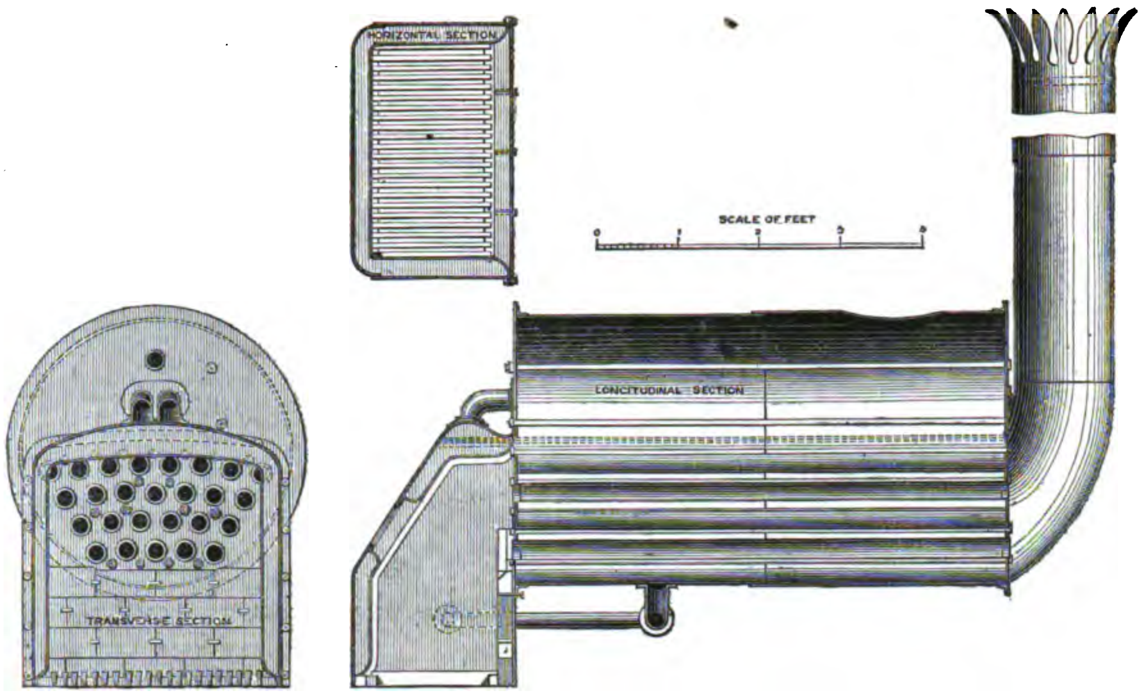
The leading features of the Rocket were as follows:—Cylinder, diameter 8 in.; stroke, 14 in.; driving wheels, 4 ft. 8 in.; trailing wheels, 2 ft. 10 in.; heating surface, 144 square ft.; weight of engine, 4¼ tons; weight of tender, 3¼ tons; horse power, 40; evaporating power, 18·24 cubic ft. of water per hour; coke per cubic foot, water evaporated, 11·7 lbs.; maximum speed, 29 miles per hour; average speed, 13·8 miles per hour.

In the largest narrow gauge engines now constructed, the heating surface has been increased from 144 to 1620 square feet, or 12 times that; the weight of an engine from 4¼ to 38 tons; the horse power from 40 to 1300.

Since the commencement of the manufacture of locomotives about 2400 have been turned out by the manufacturers of Newcastle, and upwards of 900 of these have been sent abroad.

Taking an average cost of £2000, from the commencement to this time, the gross value of the exported locomotives from Newcastle amount to	£1,800,000
Adding those manufactured for use in Great Britain and Ireland at £1500, would give a further sum of ..	2,700,000
Making the gross value of the locomotives from Newcastle to amount in all, since the commencement of the manufacture, to	£4,500,000

Of the £4,500,000 nearly one-half is represented by material purchased by the manufacturers in various stages of completion. Thus work to the value of upwards of £2,000,000 has been furnished by the manufacturers of Newcastle to the other branches of industry connected with their trade.



Transverse, Horizontal, and Longitudinal Sections of the "Rocket."

REPORTS ON THE IMPROVEMENTS

INTRODUCED IN

THE RIVERS OF THE DISTRICT.

THE TYNE	... ...	J. F. URE, C.E.
THE WEAR	... ...	T. MEIK, C.E.
THE TEES	... ...	J. FOWLER, C.E.

ON THE

IMPROVEMENTS NOW BEING CARRIED OUT

IN

THE RIVER TYNE.

BY

JOHN FRANCIS URE, C.E.

The intention of the present paper is to give a short account of the improvement of the River Tyne under the plans now being carried out.

When the writer was appointed engineer to the Tyne Improvement Commissioners, in 1859, certain works had been constructed and others were in progress.

Of these, the most important were the river walls, which had been partially constructed between the Bill Point and the Jarrow Slake, very much according to the plan laid down by the late Mr. Rennie, in 1813; the Northumberland Dock, made by the River Commissioners, having an area of about 50 acres, opened in 1857; the Tyne Dock, of a similar area, by the North-Eastern Railway Company, opened in 1859; and the Piers Works at the entrance of the river, now about half completed, and then about half their present extent.

The river at that period (1859) was much the same as in 1855, when its state was examined, and, after a long and careful inquiry, reported on by a Royal Commission, of whom the late Mr. Brunel, Admirals Bowles and Fitzroy, Lieut.-General Sir John Bell, and Robert Armstrong, Q.C., were the members. They state in their report, in relation to the past history of the river, as follows:—

During the last two or three centuries all the evidence would lead to the conclusion that a very general similarity has been maintained in the state of the Tyne notwithstanding local and partial changes.

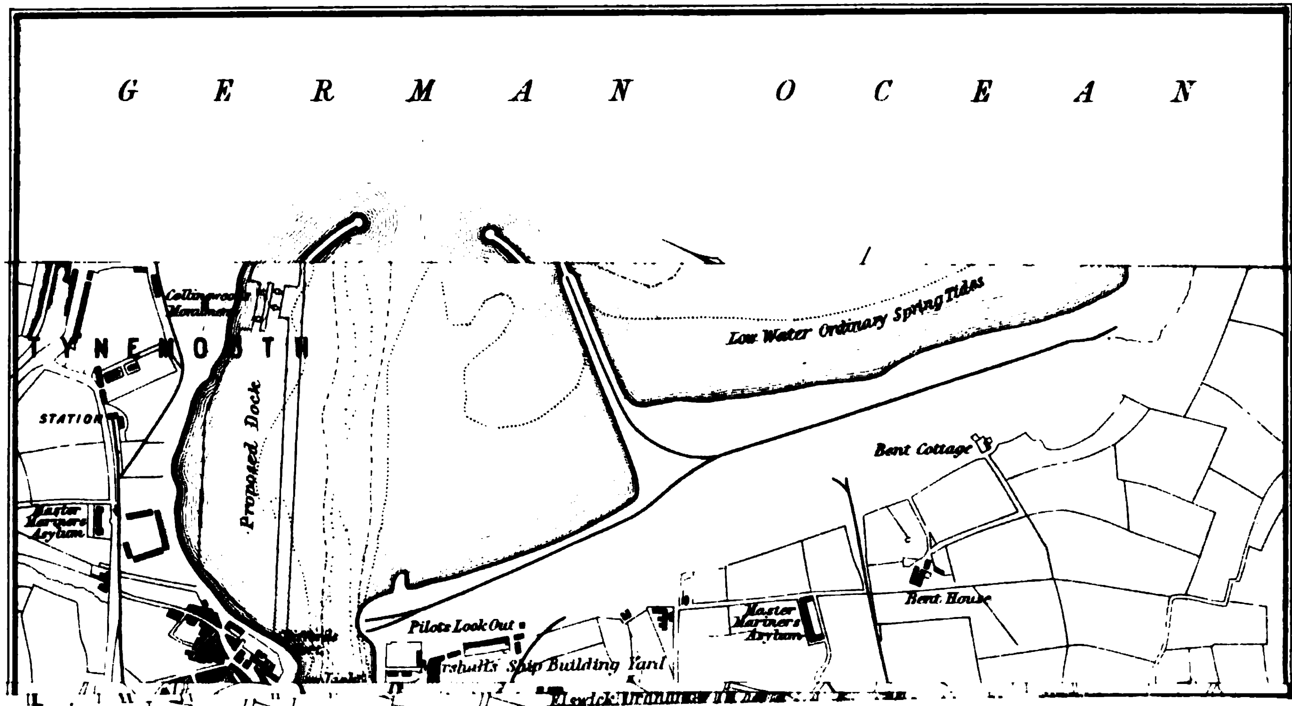
In the present century much more exact surveys have shown a similar result, namely, that notwithstanding encroachments on both banks, and many artificial works executed with various objects, the navigable state of the river has not been

much altered. Whether it has been improved, and whether the works in progress are likely to improve it or otherwise, are matters of opinion, rather than fact, on which parties differ materially; but the preponderating evidence of good authorities encourages a belief in some improvement.

That this should still be only matter of opinion needs explanation. Formerly ships sailed up and down this river, and required greater width of channel than is now wanted for steam navigation. At present the channel is less winding and deeper, but it is not so wide as it was; and although the passage for steam-moved vessels appears to be improved, the navigable condition for ships under sail, except with a fair wind, is probably to a certain extent deteriorated.

When the writer came to consider the state of the river, with the view of recommending a plan for its improvement, he found the accommodation for vessels resorting to it to be very deficient; the expenses for lighterage, from the manufactories which are principally situated in the upper part of the river, to the larger class of vessels which did not ascend above Shields harbour, to be large; the shifting character of the sands rendered uncertain the depth at the coal shipping places and factories on the banks; it was not unusual for vessels to be detained two months, and even longer, with their crews on board waiting for moderate weather, with a tide sufficiently high to be able to cross the bar; deeply laden inward bound ships had a corresponding difficulty in arriving, which operated to prevent the Tyne becoming an import port; its entrance was dangerous with on-shore gales; the Insand and Middle-ground stretched nearly across the entrance to the harbour, and in rounding it, vessels, particularly if long and deep laden, had to come nearly broadside on to the tide, when much damage was done, especially when vessels left in fleets, which was frequently the case after stormy weather, to the extent of 200 and 300 vessels in one tide, in addition to those entering. This danger became of increasing magnitude with the increasing size of vessels. The passage through Shields harbour was very shoal, so that deep-laden vessels could not leave the docks and take the bar at high water of the same tide, which involved their staying in the harbour after leaving the docks till high water of the following tide, thereby incurring considerably increased expense.

Between the Northumberland Dock and Newcastle, the small river steamers grounded on some of the shoals for two and three hours at low water of spring tides, and vessels of but small draft, about 13 to 15 feet, could ascend the river to Newcastle, and these only at spring tides. Above Newcastle the navigation was only used by keels, which were interrupted in their passage by not being able to pass over the Scotswood shoal at high water of neap tides.


G E R M A N O C E A N
TYNEMOUTH
STATION
Master Mariners Asylum
Proposed Dock
Low Water Ordinary Spring Tides
Bent Cottage
Bent House
Pilots Look Out
Ship Building Yard
Master Mariners Asylum

The deficiences in the navigation were comparatively little felt in the olden time, when the Tyne was the only outlet for the comparatively small produce of the coal-fields of Durham and Northumberland in the class of vessels of about 16 feet draft, then mostly employed in carrying on the trade—which was principally coasting and short foreign—but when a larger and deeper drafted class of vessels came to trade to the port, to carry the greatly increased quantities of coal required to supply the steam marine of a large portion of the world, the detentions and risks became serious.

These inconveniences, and their consequent expense, were the cause of much serious complaint, and were diverting the trade and commerce natural to the river—which the railway system made easy to do—to be developed at other places where improved provision had been made for its accommodation.

Having explained some of the commercial features of the time when the writer had the plan for the improvement of the river under consideration, he will now give a few of its principal physical features from observations then taken. The rise of an average spring tide at

	Ft.	In.
Tynemouth, was about	14	8
Hebburn	12	3
Below Newcastle Bridge	11	9
Above Newcastle Bridge	11	5
Scotswood	7	9
Newburn...	3	11

Ryton was the limit of the tidal flow, and of the Conservancy.

The high water of average spring tides was level between the sea and Newcastle, and rose about 12 inches higher at Newburn; but very high spring tides scarcely filled the tidal receptacle at Newcastle.

The high water of an average neap tide rises 4 to 5 inches higher at Newcastle, and about 11 inches higher at Scotswood than at sea; it does not reach Newburn. The rise of an average neap tide was, at

	Ft.	In.
Tynemouth	6	6
Hebburn	6	6
Below Newcastle Bridge	6	7
Above Newcastle Bridge	6	7
Scotswood	3	5

The high water of average spring tides rose higher than the high water of average neap tides, about 4 feet at Tynemouth, 3½ feet at Newcastle, and 3½ feet at Scotswood.

The average travel of the tidal wave between Tynemouth and Newcastle varied, but with average tides it was 8 to 12 miles per hour, and the spring tide wave between Newcastle and Newburn was about 12 to 18 miles per hour.

At that time, during average spring tides, there was 20½ feet of water at high tide on the bar. Within the bar, near to the Narrows, on the north side of the channel, a dangerous hard projection called the "Stones" existed, but which had been partially removed; and immediately above, on the opposite side of the river, projected the Insand and Middle-ground. A little further up from the north shore projected the Dortwick sand, with about 6 feet on it at low water; higher up was the Jarrow shoal, above which there were several shoals having not more than 3, 4, and 5 feet on them at low tide. Above Newcastle, at low water, the bed of the river was a great sandbank, through which the land waters drained—a great portion of the channel not being more than a few inches, and most of the remainder not more than from 2 to 3 feet deep.

The places where trade was conducted and vessels lay were mostly at the bends on the concave side of the river, where the current had scoured deep water, as between the Low Lighthouse and New Quay, North Shields, where the depth at low water was 15 feet to 21 feet; opposite South Shields, between Panash Point and Tyne Docks, depth 12 feet to 18 feet; the Killingworth Staiths, 10 feet; the Pelaw Staiths, 10 feet to 12 feet; the Tyne Main Staiths, 7 feet to 8 feet; Blaydon, 3 feet to 5 feet, and several other such places; and Newcastle, where the deepening of the channel was due to the contraction of its width, the depth at the Quays was 5 feet to 6 feet, with two short berths about 13 feet.

A general comparison of the observations taken by me in 1859, with those left on record by Mr. Rennie, taken in 1813, shows the high water to be about the same at both periods, but that the low water level at Newcastle had been depressed during that period about 14 to 18 inches, lessening toward the sea.

In the year 1859, the number of vessels that arrived in the river was 18,878, having 3,143,857 register tonnage, and they carried altogether, including imports, exports, ballast, &c., about 5,500,000 tons; there was, in addition, carried on the river in keels, about 2,000,000 tons, and about 1,000,000 tons of dredging material and factory rubbish carried along the river to be deposited at sea.

With these data, the writer prepared a plan by which he intended to take a comprehensive view of river improvement, and which could not

fail, if successfully carried out, to benefit materially all the interests situated on the banks of the Tyne. This, plan, in 1860, was submitted to the River Commissioners, and approved by them; and received the sanction of Parliament in the session of 1861.

A portion of the plan sanctioned by Parliament was a dock of about 40 acres area, known by the name of the Low Lights Dock, designed with the view of affording better accommodation to the larger class of vessels, effecting a saving in towage and pilotage, and enabling that portion of the steam coal-field which is situated on the seaboard to ship the coals from it with a somewhat shorter railway lead; but as the dock does not necessarily form a portion of the river improvement, which it is the intention of this paper to draw attention to, it will not be further alluded to.

The plan of river improvement contemplated the deepening, widening, and straightening of the river, from the sea to the limits of the Commissioners' jurisdiction, near Ryton, a distance of nearly 20 miles inland, so as to make a channel easily navigable for the largest vessels, between the sea and Shields harbour, the docks there, and Newcastle; and for such a class of vessels in the upper part of the river as can be passed under the High Level Bridge, at Newcastle, a sufficient depth of water to be carried up to the river walls for the purposes of traders having establishments on the banks.

To give effect to these views, the plan provided for a depth at high water average spring tides of 29 feet from the sea to the docks; thence to Newcastle, 26 feet; and thence to Ryton (the boundary of the Commissioners' jurisdiction) 23 feet; at average neap tides, the high-water depth would be about 3 to 4 feet less.

This would give a low-water depth at spring tides of about 15 feet up to the docks, 12 to 13 feet thence to Newcastle; and above Newcastle, 10 to 11 feet; at average neap tides the depth would be 3 to 4 feet more; and to give a safe and easy navigation at the abrupt bends, for the larger class of vessels expected to use the river in its improved condition, it was intended to remove all projecting points that would be difficult to navigate, as, for instance, the Stones, the Insand and Middle-ground, Whitehill Point, Bill Point, Bill Quay Point, Felling Copperas Point, Friars Goose Point, and other smaller points; and above bridge, to cut a straight channel between Scotswood and Lemington, and to remove other projections, and form a uniform navigable channel, leaving the existing channel at Blaydon to be deepened and used as a tidal basin for the accommodation of the trade located there.

The width of the river would then be—in Shields harbour, 1000 to 1400 feet; gradually diminishing to 850 feet at Howdon; 700 feet at Hebburn; 500 feet at Newcastle, except at the narrowest part, where the Quay walls are already constructed to the limited width of 350 to 400 feet; 500 feet above Newcastle Bridge; 450 feet at Scotswood; and 400 feet at the boundary near Ryton.

To admit masted ships into the upper river, a bridge, in lieu of the existing Town Bridge at Newcastle, was provided; the two centre spans, each 100 feet wide, to swing open; when it was expected that sailing vessels up to 400 tons, screw steamers up to 1000 or 1200 tons, would use the upper river, and receive their cargoes without transhipment or lighterage; and that vessels of any size, the Great Eastern not excepted, could be built and engined there.

The estimated capital expenditure to complete these works, with the purchase of land, &c., was £950,000.

The improvements just indicated would, when executed, give to the river a channel greatly exceeding its natural capacity, the formation of which the writer intended to accomplish and maintain by dredging; and remove the projecting points by blasting, excavating, diving, and the other usual means. The cost of maintenance of this channel he estimated to be moderate.

The piers at the entrance of the river, which were being carried out under the direction of the late Mr. Walker, the writer relied on for shelter when dredging in the open sea; but from the slow progress which these works have made, he has not yet received the full benefit from this source that he expected, though no doubt it will be so as they advance. These works have already considerably protected the entrance to the port, and will increase in value as they approach completion, by giving increased shelter to vessels entering the harbour, by dispersing and dissipating the waves after they have passed their heads, thus enabling vessels to bring up in comparatively quiet water; and the shelter so afforded will permit of the dredging machinery being applied effectually to deepen any requisite area inside of them that may be found requisite either for refuge or the ordinary operations of commerce.

The estimated expenditure to complete the piers into a depth of thirty feet at low water, as made by Mr. Walker, was £660,000, that being the depth into which the Commissioners have at present resolved to carry them.

When the improvements of the river are carried out, the writer anticipates that the high water will rise about one foot higher at

Newcastle, and two feet higher at Ryton than at the sea; that the tidal column at the sea will be carried inland to the limits of the improvements; that the tidal wave will be accelerated to an average speed of sixteen to twenty miles per hour; and that the great additional momentum due to the increased column of tide and greater area of receptacle, chiefly in the upper parts of the river, and the increased sectional area of the channel, by allowing a more rapid discharge of the freshes, will greatly add to the scouring power of the tidal and flood waters on the river, but more especially on its sea channels.

Towards carrying out these works some propress has been made.

The Stones, the Insand and Middle-ground, the Dortwick Sand, a large portion of the Whitehill Point have been removed, the general river has been deepened to such an extent that there will be shortly—probably during the present year—the depth of water, between the sea and the docks, contemplated by the original plan. The river up to Newcastle has been so far improved, about two to three feet, that the small passenger steamboats are never interrupted in their passage at low water, and the passenger steamboat traffic has thus been enabled to be established, the increased depth at the same time benefitting the general trade, and the upper river can be navigated by keels during all tides.

There has been already provided, or is under contract for delivery during the next three months, dredging plant consisting of six dredging machines, seven tug steamboats, forty hopper barges, ten screw hopper barges, ten craft, repairing shops, &c., of the value of about £250,000, which is capable of raising out of the bed of the river about two and a half to three millions of cubic yards per annum.

Plans are in progress, and nearly completed, for the removal of Bill Point and Friars' Goose Point, and the reconstruction of Newcastle Town Bridge as an opening bridge.

The writer has hitherto every reason to be satisfied with the results attending the prosecution of these works, and does not entertain any doubt of their ultimate success. He fully expects that in about four years hence the improvement will be completed up to Newcastle, and in about four years afterwards up to the boundary at Ryton.

The only modification of the plans just described is the endeavour now being made to bring 20 feet water at low tide from the sea into Shields harbour in place of 15 feet, as originally intended; and the only further deviation at present contemplated is, to make a portion of Shields harbour and adjoining river 26 to 28 feet deep at low tide, in place of 15 feet, as originally intended, in order that the very largest vessels may

then be able to float there at all times of tide; a result which it is hoped may be accomplished during the next or following year.

Already, with the improvements made, there is little detention to shipping, and large vessels are frequenting the port in increasing numbers. The ease of entrance, as well as exit, combined with providing proper accommodation for cargo, will, the writer anticipates, at no distant date, be the means of establishing an import trade, as ships chiefly now arrive light in ballast. And he would expect that the general facilities afforded by an improved river, which, in fact, will become a deep and spacious harbour, nearly 20 miles long, and from 400 to 1400 feet wide, will be so valuable as to add vastly to the industrial pursuits and commerce carried on on its banks; and by no means the least expectation he ventures to indulge is the hope that the vessels of Her Majesty's Navy—the Channel Fleet, if wished—may freely enter and leave our port, and be well accommodated when in it.

STATEMENT OF THE QUANTITIES OF DREDGING PERFORMED IN THE RIVER TYNE AND NORTHUMBERLAND DOCK SINCE THE COMMENCEMENT OF DREDGING.

Years.	Old* Dredger.	No. 1† Tyne Dredger.	No. 2‡ Newcastle Dredger.	Fanny§ Dredger.	No. 3¶ Dredger.	No. 4** Dredger.	No. 5†† Dredger.	No. 6‡‡ Dredger.	TOTALS.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1838	21,579	......	......	......	......	......	......	......	21,579
1839	40,205	......	......	......	......	......	......	......	40,205
1840	16,260	......	......	......	......	......	......	......	16,260
1841	14,515	......	......	......	......	......	......	......	14,515
1842	21,948	......	......	......	......	......	......	......	21,948
1843	2,296	13,020	......	......	......	......	......	......	15,316
1844	......	25,199	......	......	......	......	......	......	25,199
1845	......	63,237	......	......	......	......	......	......	63,237
1846	......	33,333	......	......	......	......	......	......	33,333
1847	......	58,896	......	......	......	......	......	......	58,396
1848	......	41,993	......	......	......	......	......	......	41,993
1849	......	74,993	......	......	......	......	......	......	74,993
1850	......	66,452	......	......	......	......	......	......	66,452
1851	......	79,221	......	......	......	......	......	......	79,221
1852	......	91,532	......	......	......	......	......	......	91,532
1853	......	97,529	......	......	......	......	......	......	97,529
1854	......	56,376	......	......	......	......	......	......	56,376
1855	......	67,264	30,623	......	......	......	......	......	97,887
1856	......	57,181	97,028	......	......	......	......	......	154,209
1857	‖1,720	72,590	130,137	39,219	......	......	......	......	243,666
1858	......	54,396	171,868	89,153	......	......	......	......	315,417
1859	......	90,372	207,249	198,781	......	......	......	......	496,402
1860	......	124,471	282,376	266,988	......	......	......	......	673,835
1861	......	122,411	236,348	25,178	138,406	224,589	......	......	746,932
1862	......	173,795	256,581	......	582,061	852,107	......	......	1,864,544
1863	......	167,964	204,964	......	590,416	911,090	425,076	174,343	§§2,473,853
	118,523	1,631,725	1,617,174	619,319	1,310,883	1,987,786	425,076	174,343	7,884,829

* Commenced work 14th May, 1838, and ended 22nd February, 1843 † Commenced work 26th June, 1843.
‡ Commenced work 10th July, 1855. § Commenced work 29th April, 1857, and ended 14th February, 1861.
‖ A hired dredger. ¶ Commenced work 12th July, 1861. ** Commenced work 17th July, 1861.
†† Commenced work 27th July, 1863. ‡‡ Commenced work 5th October, 1863.
§§ The quantity which will be dredged this year (1864) is expected to reach between 4,000,000 to 5,000,000 tons.

ON THE

IMPROVEMENTS IN THE RIVER WEAR.

Compiled by WM. DUNCAN, from Documents furnished by THOS. MEIK, C.E.

A DETAILED account of the improvements that have taken place in the river Wear and at the port of Sunderland since the year 1717, when an Act was passed appointing a body of Commissioners charged with the conservancy of the river, would be a history of a marvellous series of changes in the physical features of a stream but indifferently favoured by Nature for subserving the purposes of commerce. Instead, however, of minutely recapitulating the progressive improvements, we shall merely glance at their leading features, and show how they have tended to increase the trade of the port, and to stimulate the industrial energies of the people of Sunderland.

The jurisdiction of the Commissioners over the river extends to Biddick Ford, about 9 miles from the bar; within the port and haven their boundaries are—From Souter Point, about 2½ miles from the bar, towards the N.E., and so into the sea to 10 fathoms at low water; and from thence in a direct line until it falls opposite to Ryhope Dene, about 4 miles towards the south.

Passing over various important works carried out within these limits by the early engineers to the Commissioners, in the construction and lengthening of piers, and in removing obstacles to the safe navigation of the lower part of the river, we come to the year 1813, when the Commissioners resisted certain encroachments which had been attempted on the shores of the Wear, on the ground that embanking the salt marshes in the higher reaches would be injurious to the navigation. Following this step on the part of the Commissioners, a survey of the river, port, and haven was carried out, in accordance with the provisions of a new Act of Parliament, by Mr. Giles, under the instructions of Mr. Rennie, and, on his death, it was completed by his son, afterwards Sir John Rennie.

Upon the chart drawn up from this survey was delineated a line called "The Quay Line," beyond which it was not lawful for any person to erect any work whatsoever. This quay line was confirmed by a subsequent Act of Parliament (11 Geo. IV.) in terms of which the Admiralty exercises a controlling power over all quays built on the river.

While provision was thus being made for conserving the tidal flow of the Wear, great improvements had been effected at the mouth of the river, and up to the year 1843 operations were from time to time carried on with the view of extending and strengthening the piers, which by that time had been carried out to their present length, viz , the north to 1050 feet, and the south to 1600 feet. The narrowest width of the harbour mouth was 320 feet, and on the bar there was a depth of 4 feet at low water of ordinary spring tides. It is interesting to note the great fluctuations which have taken place in the depth of water on the bar. In 1688 it was 1 foot; and in 1737 it remained the same. In 1832 it was 2 feet 10 inches; and in 1844 it was, and at present is, about 4½ feet. At the time of its greatest depth in 1844, and at various periods since that date, the Commissioners have dredged the bar, and these operations have materially assisted in the maintenance of that depth. The average quantity of material raised since 1844 from the river and docks will be about 360,000 tons, at an average cost of 4d. per ton.

Notwithstanding the improvements which had been carried out by the Commissioners, much inconvenience began to be felt between the years 1825 and 1830 through the limited accommodation afforded by the harbour for the mooring of large fleets, and great dissatisfaction was caused by the injury which large and valuable vessels occasionally sustained in the river. The average breadth of the harbour was about 350 feet, and its actual capacity did not exceed 80 acres. Schemes for the formation of wet docks had been propounded, in 1794, by Dodds; in 1807, by Jessop; in 1829, by Robert Stevenson, of Edinburgh; and in 1831, by Brunel and Giles. The plans of the two latter engineers were submitted to Parliament, but both were rejected. Mr. George Rennie and Mr. Walker were employed, in 1832, to prepare designs for a small dock on each side of the river, and the Commissioners deposited these plans in Parliament; but they abandoned the north side dock, in consequence of a wish expressed by the original proprietors to carry out the plans themselves under the sanction of a charter, while, on the south side, they were threatened with an opposition sufficiently powerful to lead them to give up the project. In 1835, however, "Wearmouth

Dock" was commenced on the north side by a private company. Its whole extent was under six acres, and in 1838 it was opened for traffic. Independent of its unsuitableness in several other respects, it laboured under the serious disadvantage of its entrance being exposed to the range of heavy seas that rolled up the harbour in stormy weather. It never remunerated its proprietary; and in 1847 it was sold by them to the York, Newcastle, and Berwick Railway Company—now incorporated with the North Eastern Railway Company—in whose possession it still remains. In the session of 1846, Parliament sanctioned a project for the construction of docks on the south side of the river. Mr. George Hudson, then one of the members for the borough, was the chief supporter of the scheme, for the carrying out of which a joint-stock Company was formed.

Reverting to operations on the river, we find that the great feature of harbour improvement—the Quay Line—had by this time scarcely got beyond the drawing on the chart which Giles prepared and Rennie sanctioned. The great difficulty was to give the utmost accommodation to the landowners, and yet to preserve the river. Many impediments, consequently, presented themselves, arising from the points at the bends of the river, or from the projection of existing works, both of which would have caused too great an expense to remove. Any general scheme of improvement in the upper part of the stream was therefore abandoned, and conservancy only was aimed at; but measures were adopted for directing the tidal water into the main channel, while, by persistent dredging of the lower part of the river, and facilitating the ebb of the tidal water, a scour was created which operated beneficially upon the whole extent of the stream. In this improvement the construction of the piers and other works had materially assisted.

The conflicting opinions of experienced engineers on the effects of the piers is rather remarkably illustrated by a comparison of the views of Mr. Jessop, the engineer to the Commissioners at the beginning of the present century, and those of Sir John Rennie, as expressed in a discussion which followed the reading of a paper, by Mr. Murray, on Sunderland Harbour, at a meeting of the Institution of Civil Engineers, in May, 1847. Forty years previous, Mr. Jessop made a report to the Commissioners, in which he says he "is of opinion that it would have been very desirable if the whole of the South Pier had been carried out more southerly, either in the direction proposed by Mr. Smeaton, or still more to the south, so as to have increased the capacity of the harbour without

increasing the width of its entrance." On the other hand, Sir John Rennie, speaking with the result of accomplished facts before him, says, "Several engineers had, in their reports, insisted strongly upon the extremity of the South Pier pointing in a southerly direction. It was certain, if that system had been persevered in, the harbour would have been destroyed."

The commencement of Sunderland Docks introduced a new era in the progress of the port; for, with the existence of a company having in certain respects rival interests, the Commissioners seem to have made special efforts to improve the position of the Trust, whose income they saw would be considerably increased by the dues to be derived from coals shipped in the docks. On turning to the reports of Mr. Meik (who had succeeded Mr. Murray as engineer to the Commissioners) we find, that in June, 1850, the attention of the Board was directed to the propriety of carrying out certain works, mainly for the purpose of breaking the roll of the sea up the harbour. In accordance with instructions from the Commissioners, Messrs. David and Thomas Stevenson subsequently reported on the agitation in the lower harbour, and on the question of river improvement generally. They recommended the execution of some extensive works, a portion of which, as originally suggested by Mr. Meik, was ultimately carried out, in the removal of a considerable part of the South Pier, to admit of the formation of a silting basin; the result of which was soon made manifest in a great diminution of the sea disturbance in the harbour.

The great revolution in shipbuilding, caused by the introduction of iron, began to show its effects about this period; and in July, 1852, Mr. Meik proposed an abandonment of the quay line of 1819, as laid down by Sir John Rennie, with the view, principally, of affording facilities for iron shipbuilding, by increasing the available land along the river side. He submitted that the progress of engineering science since the date of Rennie's plan had shown that there was little or no advantage to be derived from allowing water to spend itself over large flats and salt grasses, and that the adoption of the quayage which he proposed in place of Rennie's would, in conjunction with a deepening of the river in its higher reaches, increase the range of the tidal flow, and yield a clear gain of ten million cubic feet of tidal water entering and leaving the river twice in every 24 hours. In closing his report Mr. Meik thus anticipates a state of things which has since been fully realized:—"I need not mention that iron screw colliers are at present building for our coasting

trade. What may be the result of the substitution of such vessels for our sailing colliers is difficult to predict; but, should they prove successful, iron will become general in shipbuilding, and the coal trade will be revolutionized."

Much discussion followed at different meetings of the Commissioners upon the proposed radical alteration of the quay line, which was ultimately adopted, and in October, 1853, received the statutory sanction of the Admiralty. During all this time dredging operations were steadily persevered in from Pallion (about 3 miles from the bar) to the mouth of the harbour. Pallion Caunch and the Minikin Sands—two serious obstacles to the navigation of the upper reaches—were removed, and the quay line having been partially carried out, a marked improvement in the depth of water resulted at different points where the owners of the land had carried out quays to the new line.

The construction of the docks, as already stated, commenced in 1848, the land on which they were built presenting the somewhat peculiar feature of being artificially formed. For many years the sea had been making rapid encroachments on the Town Moor. To prevent this, Mr. Murray, engineer to the Dock Company, threw out various groynes or jetties, the effect of which was the trapping and accumulation of masses of sand and shingle, so as to form an artificial beach, which acted as a barrier to the sea, and preserved the Moor from further destruction. In carrying out this novel system of land-making, the dock wall was made to extend parallel to the Moor, being distant the width of the dock from the edge of Moor, and this wall was supported and strengthened by the groynes already referred to. These groynes (some of which, on a smaller scale, have been formed to the east of the existing docks) were strong arches of masonry, filled up with rocks and stones within, and somewhat resembled a cone cut up the middle and laid on a flat surface. They were about 500 feet in length and 20 feet high at their highest end, gradually tapering to the other point, which extended seaward nearly at right angles to the coast. They were placed at distances averaging from 400 to 500 feet from each other, and the intervals between them were gradually filled in, partly by the deposits washed into them by the sea, but chiefly by excavations from the site of the docks.

The works were carried to a successful termination, and on the 20th of June, 1850, the "South Dock" was formally opened, the entire water space, including the half-tide basin, being 21½ acres. The grand feature in connection with this great addition to the shipping accommodation of

the port was the formation of an outlet with a half-tide basin of 1½ acres leading direct from the docks into the sea, independent of the river. This gigantic undertaking was not completed until the year 1856, by which time an extension of 13 acres to the original dock space was also finished, the cost of the docks and outlet having been about £700,000. By means of the sea outlet, a rapid bound was at once made in the commercial position of the port. Until that work was carried out, vessels of more than 700 or 800 tons burthen did not resort to Sunderland, but a depth of water equal to 22½ feet on the outlet's inner sill at high water of spring tides (being 4 or 5 feet more than on the bar of the river) began at once to attract ships of 1,000 or 1,200 tons and upwards to the docks. In a few years we accordingly find that the exports of coal had risen enormously. In 1846 they amounted to 1,381,262 tons; in 1857 they had reached 2,483,116 tons; while the increase in the average tonnage of vessels built in the port had increased fully 20 per cent. Advantages resulting from this state of things were soon experienced throughout the borough, and in the course of a few years nearly 100 new streets were laid out and upwards of 1200 houses erected. So popular, indeed, did the docks become, that notwithstanding the low rate of interest which they had yielded to the shareholders, the Commissioners, in deference to the almost unanimous wish of the inhabitants, as well as in accordance with their own desire to put an end to rival and occasionally conflicting interests, promoted a bill in the Parliamentary session of 1859 for the purchase of the Docks by the Trust. The bill eventually passed, and under its provisions the Commission, which had previously been a self-elected, became in a great measure a popularly-chosen body. Under the Act of 1859, several new works on a large scale have either been carried out, or are in course of construction, designed by Mr. Meik, and executed under his direction; chief amongst which is a further extension of the docks and sea outlet, by which 6 acres will be added to the docks in the spring of 1866, making a total of 42 acres of dock accommodation, inclusive of basins. When the extension of the outlet is completed, its piers will enclose a water area of 28 acres, with the advantage of an additional means of communication between the outlet and the docks. A second and much larger graving dock than the one now in use will be finished in November, 1864, and by the end of 1865 the harbour, at the Narrows, will be cleared, at a cost of £6,000 or £8,000, of a series of rocks which imperil the safe navigation of the larger class of screw colliers that now load above Wearmouth Bridge.

In summing up the extent of industrial progress on the Wear at different periods within the present century the following facts may be presented by way of contrast:—

In the year 1800, the gross annual revenue of the Commissioners was £5,000. Between 1840 and 1850 it ranged from £12,000 to £15,000. In 1863 (4 years after the purchase of the docks) the gross receipts from the docks were £52,036; from the river, £35,542; making a total of £87,578, out of which, however, there had to be paid a sum of £18,326 as interest to the shareholders of the docks.

In 1800 the number of vessels registered at the port was 514; in 1829, 625; in 1863, 1,000, with an aggregate tonnage of 232,077.

In 1825 the exports of coal amounted to 1,330,414 tons; in 1863, to 3,081,166 tons.

In 1845, 7,036 vessels cleared from the port; in 1863, 11,889.

In 1835, 98 vessels, representing an aggregate tonnage of 26,134, were launched on the Wear; in 1863, 171, with an aggregate tonnage of 70,140, the total value of which would be about three-quarters of a million sterling.

In 1800 the Customs' receipts were £11,480; in 1863, £87,000.

At the beginning of the century the glass trade of Sunderland was quite insignificant; now, there is yearly manufactured about 7,000 tons of window glass and 23 millions of glass bottles, the aggregate value of which is nearly £300,000.

In the midst of all this material progress, the population of the borough has increased in a corresponding ratio. In 1802 it numbered 19,120; in 1851, 63,897; at the census, in 1861, within the Parliamentary boundary, it was 85,748; within the municipal boundary, 80,324.

Other statistics might be quoted to show the extraordinary impetus which has been given of late years to the manufactures of the borough; but although they might fairly be cited as the immediate results of the policy which has been adopted in regulating the affairs of the port, they could not be legitimately embodied in a paper which professes to treat mainly of the river Wear and docks at Sunderland.

EXPORTS FROM SUNDERLAND OF COAL AND COKE.

Year.	Tons.	Year.	Tons.
1825	1,330,414	1845	1,414,339
1826	1,373,455	1846	1,381,262
1827	1,308,225	1847	1,621,303
1828	1,326,593	1848	1,662,695
1829	1,497,059	1849	1,519,354
1830	1,387,426	†1850	1,718,427
1831	1,255,896	1851	1,643,024
1832	1,203,802	1852	1,789,795
1833	1,349,058	1853	1,838,867
1834	1,111,760	1854	1,871,353
1835	1,088,829	1855	1,890,926
1836	1,155,414	1856	2,204,898
1837	1,331,438	1857	2,483,116
1838	1,277,549	1858	2,560,104
1839	1,282,486	‡1859	2,606,518
*1840	1,318,497	1860	2,979,468
1841	1,348,980	1861	3,108,462
1842	1,242,051	1862	3,151,027
1843	1,194,723	1863	3,081,166
1844	1,045,351		

MISCELLANEOUS IMPORTS AND EXPORTS IN 1863.

IMPORTS.

Timber	117,216 loads.
Iron	11,450 tons.
Grain	70,757 qrs.
Chalk and pyrites, &c.	30,649 tons.
Props	106,234 doz.
Flour	2,255 tons.

EXPORTS.

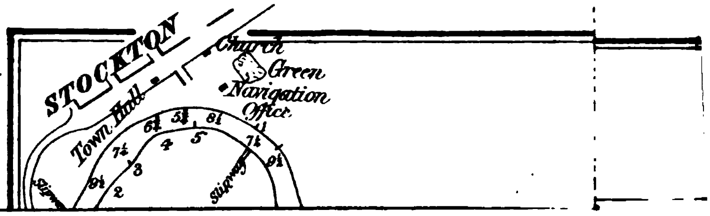
Bottles	14,878 tons.
Earthenware	3,734 crates.
Lime	41,177 tons.
Iron	31,381 tons.

* North Dock opened. † South Dock opened.
‡ South Dock passed into the hands of River Wear Commissioners, July, 1859.

SHIPBUILDING ON THE WEAR.

Year.	No. of Vessels.	Total Tonnage.	Average Tonnage.
1835	98	26,134	266¾
1836	114	27,703	243
1837	128	32,343	252¼
1838	180	43,512	242
1839	247	59,441	240½
1840	251	64,446	256¾
1841	141	40,396	286¼
1842	107	26,837	250¼
1843	85	21,377	250½
1844	100	27,131	271¼
1845	131	38,260	225
1846	133	41,835	314½
1847	148	46,901	316¾
1848	142	37,878	266¾
1849	155	44,333	292
1850	158	51,374	325¼
1851	146	51,823	355
1852	142	56,645	399
1853	153	68,735	449¼
1854	151	66,929	443¼
1855	151	61,159	405¼
1856	154	63,049	409
1857	143	54,780	383
1858	110	42,008	381⅞
1859	100	37,184	371⅞
1860	112	40,201	355⅞
1861	126	46,778	371¼
1862	160	56,921	355¾
1863	171	70,140	410

The aggregate tonnage for the year 1863 included 17,724 of iron steam and sailing vessels.


STOCKTON
Town Hall
Church
Green
Navigation Office
Slipway

ON

HE IMPROVEMENTS IN THE RIVER TEES.

BY

J. FOWLER, C.E.

HE Tees takes its rise in the mountain range which marks the meeting f the counties of Cumberland, Westmoreland, and Durham. After ursuing a circuitous easterly course for about 100 miles—during a onsiderable part of which it separates the county of Durham from Yorkshire—it falls into the German Ocean. The area of its basin is upwards of 700 square miles. Below Stockton Bridge, though its banks widened, its circuitous character was still retained. There, also, a new feature in the shape of islands appeared; and as these were attended with sandbanks and shoals, which shifted with the variation of the wind and current, they proved a great drawback to the trade of the river, as they rendered its navigation at once uncertain and difficult. Indeed, it was nothing uncommon for vessels to be as long in reaching Stockton, after entering the river, as in sailing from London to the Tees. Between Cargofleet and the sea, it expands into an estuary of 13 square miles, the bed of which is for the most part composed of loose moveable sand. The tide flows to Highford, above Worsal, which is distant about 27 miles from the sea. For sea-going craft, however, the navigation extends only to. Yarm, 8 miles higher up the river than the town of Stockton. Yarm seems, at one time, to have been a place of considerable importance. It had its own shipbuilding yards, as well as a large export trade in grain and other agricultural produce. The erection of a stone bridge over the Tees at Stockton, between 1760-70, would appear to have given the first blow to its prosperity, and led to its gradual decline. Since then, vessels with falling masts can only reach its quays, which are now in decay; but with its large warehouses they still serve to give evidence of its better days. Immediately below Stockton there was an island

called Jenny Mills Island, and a shoal which was the measure of the available depth of water to the town. In 1804, Chapman states that he had found a cross sand running westward from the said island, below the shipyards, obliquely towards the Yorkshire shore. The sand was mostly covered, and although the channel over it was sufficiently wide, it was nowhere deep enough for a small ship's boat to get over without forcing its keel through.

From observations taken at the same time, it appears the rise of spring tides at the quays, was 8 feet, so that the available depth of water would be under 9 feet at spring tides. At Newport there was a causeway or line of stepping stones, used by the monks in travelling between Guisbro' and Hartlepool; at low water this was all but dry. Abreast of Cargofleet what is now called Cargofleet Scarf, and which was formerly known as the inner stones, had not a submergence of more than 2 feet at low water. Below the latter of these places the channel of the river had undergone very great alterations; about 100 years ago it consisted of three separate branches or channels. One of the principal of these, called the West Channel, took a northern divergence by Greatham Creek and Seaton Snook point. At this point there was a deep pool called the Lower Hole, where upwards of 100 wind bound vessels have found shelter in a single tide. Another branch called the south channel, pursued the same direction as the existing channel to the 9th buoy, or outer stones, while the third took a course a little more to the north than the last, but joined it at the 9th buoy. These channels were continually altering both as to position and depth. And their ever-shifting character must have rendered them at once perplexing and dangerous. In 1762 the course out over the bar was east, while the depth at that time, and it had been the same for some time previous, was 4 feet at low water. Then, as now, however, it was not permanent, but varied with the ever altering circumstances by which it was liable to be affected. About half a mile below Stockton, the river suddenly diverged towards the south, and after a circuitous course by Maudale and Acklam, of about 2½ miles, returned to within 220 yards of the point of divergence. In 1769, an individual named Edmund Harvey, suggested the propriety and advantage of forming a channel for the river through this neck of land. Through his representations, Jonathan Pickernell, of Whitby, was engaged by some of the principal inhabitants of Stockton and the neighbourhood, 1791, to report upon the desirableness of the undertaking, and the cost at which it could be accomplished. Nothing more

was done until 1802, when Mr. William Chapman was called in to report upon the whole scheme. His report led to the formation of a provisional committee, in 1804, and by this committee he was instructed to survey the ground, prepare plans, and make an estimate of the work to be done, that an application might be made to Parliament for the necessary powers. It was not until 1808, however, that the Tees Navigation Company was incorporated by Act of Parliament, and empowered to make a navigable cut from the east side of the River Tees, near Stockton, through the neck of land into the said river, near Portrack. No time was lost in commencing the work, and in 1810 the first cut was opened. The increased scourage occasioned by the shortening of the river course was speedily shown in the greater depth of water which it produced. So marked and palpable was the improvement, that the rise of tide at Stockton Quay, which formerly was 8 feet, was now increased to 10. But this, though an unquestionable advantage, was not equal to what was gained by the shortening of the river course, and escaping the *great circle* round which all vessels, whether outward or homeward bound, had hitherto been compelled to sail. In our day of steam power this would not perhaps be hailed as so great a boon, but let us revert to the time when, so far as ships were concerned, the only motive force was the wind, and after allowing for its uncertainty, let us take into account a channel beset by ever-shifting sandbanks, and we must see that the advantage to the perplexed and weary mariner must have been unspeakably great. Nor was the advantage confined to one particular class. The town of Stockton must have been greatly benefitted by the work. Facts, though stubborn things which cannot be denied, prove this. The tonnage of the port, which in 1804 was 21,584 tons, had risen in 1812 only two years after the opening of the first cut, to 42,904 tons.

The cut having been successfully executed, and the traffic greatly increased, the Company commenced confining and regulating the river channel between Stockton and Newport. This was attempted by constructing groynes placed transversely to the current. The revenue continued steadily progressing till September, 1825, when the opening of the Stockton and Darlington Railway, between Stockton and Shildon, gave a fresh impetus to trade, and heralded a new era in the history of commercial enterprise. So greatly did this augment the river traffic that additional improvements were seen to be absolutely imperative. Several engineers were accordingly consulted; among others Mr. H. H. Price and Mr. R. Stevenson. Both of these gentlemen furnished the Navigation

Company with plans for improving the Tees. According to Mr. Price's plan, it was proposed to cut a channel between Blue House Point and Newport, and to regulate and deepen the channel between the latter place and Cargofleet, by means of transversed jetties, with occasional longitudinal heads. There was no difference of opinion as to the propriety and importance of the cut between Blue House Point and Newport. This was proposed and advocated by both the engineers. The only difference of opinion regarded the alterations that should be made upon the river between Newport and Cargofleet. Mr. Stevenson proposed cutting a canal between these two places, or regulating the existing currents by longitudinal training walls in place of transversed jetties. His objection to jetties and preference for training walls, we give in his own words—"To project numerous jetties into the river I regard as inexpedient, being often a dangerous incumbrance to navigation, tending to distract the current and to destroy the uniformity of the bottom. I would prefer continuous, or parallel dykes, on either side, which have been successfully employed in deepening the Clyde, after its navigation had sustained material injury from a perverse system of jetties." The plan chosen and acted on by the Navigation Company was that of Mr. Price, and jetties were accordingly constructed to a much greater extent than they had ever been on the Clyde, but after a trial of 27 years it was found that they were liable to all the objections that had been urged against them by Mr. Stevenson, and a plan somewhat similar to what he recommended was introduced, and is now being acted on by the present engineer. To carry out the plans of Mr. Price the company required power to raise additional funds, and in 1828, the tonnage of the port having, in the meantime risen to 87,823 tons, the second Act was obtained which gave authority to raise £20,000 by shares, and £30,000 on mortgage. The second, or Price's cut as it is called, was 1100 yards in length, and 75 yards in breadth. It cut off the bend of the river round by Portrack, shortening it very considerably, and was opened in 1830. When this was done the Company began to construct the jetties which had been recommended to be placed in the river between Stockton and Cargofleet, with a view to fix the sandbanks and otherwise improve the navigation. In the same year the Stockton and Darlington Railway Company extended their line to Middlesbro', and the first house of that now important and still rapidly increasing town was built. Coals were at first shipped in the Tees by means of staiths, but these were found not to answer. The shifting character of the sandbanks

with which the river abounded, occasioned great and rapid variations in the depth of water at the various shipping places. This might also, to some extent, be owing to the works in progress at Bamblets Bight and Billingham Reach; but so great and rapid were the changes, that berths, which had a depth of 12 feet at low water, might be left in a few weeks completely dry. After much consultation with engineers and the Stockton and Darlington Railway Company, it was at last determined to carry the channel of the river deeper into Bamblets Bight, that the current might be permanently diverted towards, and be driven with greater force upon, the south shore immediately in front of the Middlesbro' coal staiths. In 1828, the Clarence Company obtained an Act, empowering them to construct a line of railway from the collieries near Coxhoe, to Stockton and Haverton Hill; an extension to Port Clarence was afterwards obtained, and from this place coals were first shipped in 1834. From this time the trade on both banks of the river continued rapidly to increase.

For centuries the Elder Brethren of Trinity House, Deptford Strond, had buoyed the bay and river Tees as far up as the 9th buoy; with this exception, nothing had been done below Cargofleet to fix the channel or enable the mariner to steer his proper course, either by night or day. The immense increase of traffic occasioned by the formation of railways along its banks, necessitated steps being taken to remedy this hitherto neglected evil. In their first Act, power was granted to the Navigation Company to light the bay and entrance to the Tees, and, as a remuneration for the cost and trouble, to levy light dues. Means were now taken to put in operation those hitherto dormant powers. Two leading lights were erected near Seaton, which serve to lead vessels clear of the Redcar rocks; two others were constructed on the Bransand, to lead from the former over the bar, while a light-ship was moored at the 5th buoy to mark the arrival at safe anchorage. These lights were first exhibited on the 2nd May, 1839; and the following year the tonnage of the port rose to 651,333 tons. From this time vessels could enter and leave the Tees, from the 5th buoy, either by day or night. A still further improvement, in the way of lighting, was desiderated, and was ultimately obtained, when, at the 5th buoy, masters of vessels were unwilling to remain there, and desirous of reaching Middlesbro'. This induced the shipowners of that town to club together, and erect three temporary beacons, or lanterns, at their own expense. Seeing this, the Navigation Company, in 1842, lighted the river as far up as Cargofleet. In this year, the Middlesbro' Dock was

opened, and the shipment of coals on the river, by the Stockton and Darlington Railway Company, thenceforth ceased.

No means had as yet been employed to improve the river below Cargofleet. The sandbanks were continually altering their form and position, and the stream was always divided into two and sometimes into three channels; at such times the depth in the best water was less than two feet, and generally very crooked. The casualties to vessels, and the difficulty experienced in navigating the channel, and getting the lights to lead in the best water, together with the expense incurred by the frequent removal of the buoys, beacons, and river lights, caused the attention of the Company to be directed to the improvement of that part of the navigation. Mr. Brooks was consulted, and he recommended a channel from Cargofleet to the fifth buoy, through the Seal Sands. Jetties were constructed on the south shore for the purpose of driving the channel over to the north; but these works, although part of the general plan, were only constructed bit by bit in order to get rid of temporary inconveniences as they arose. The effect of these partial works was to damage the south channel without improving the north. The Company, having exhausted their borrowing powers, could only expend their surplus revenue on the execution of their plans, and this tended to give a piecemeal character to the work.

The tonnage of the port continued, however, to increase up to 1846, where it reached its maximum, 742,521 tons. In the following year, the West Hartlepool Dock was opened, and the coals which had hitherto been shipped at Port Clarence were diverted to that harbour. The navigation between Middlesbro' and the bar continued to grow worse; that—combined with the falling off of the dues, which had been leased to the Stockton and Darlington Railway Company, since 1845—induced the latter Company, in 1850, to give notice of their intention to apply to Parliament the following session, for an Act to take the conservancy of the river out of the hands of the Company, and vest it in a public commission. The Navigation Company successfully opposed this measure, but pledged themselves to bring in a Bill the following session to accomplish, in a better form, the object which all saw to be necessary.

The Act of 1852 was, accordingly, obtained by the Navigation Company, and the conservancy of the river was by it vested in a public commission, consisting of 15 members appointed in the following manner :—3 by the Board of Trade; 2 by the Ratepayers of Yarm; 5 by the Town Council of Stockton, and 5 by the Town Council of

Middlesbro'. At that time the navigation between Middlesbro' and the 9th buoy was in a very bad state; the stream was divided into three channels, and in the best of these three there was not more than 1 foot 10 inches at low water, spring tides; all the channels were very crooked, and consequently very difficult of navigation. The erection of jetties, as recommended by Mr. Price, tended at first to improve the channel between Stockton and Middlesbro'; but, as we have already noticed, the evils with which Mr. Stevenson represented them as being connected, very soon began to show themselves. As the alluvial matter accumulated on the foreshore, the depth of the channel began to lessen, deep holes were formed at the end of the jetties, while shoals collected both above and below them. To remedy this state of things, the engineer, as we also formerly observed, recommended the adoption of a plan similar to what had been proposed by Mr. Stevenson, and immediate steps were taken for having the necessary working plans and sections prepared and sanctioned by the Admiralty, and also plans of dredging machinery for the purpose of deepening Cargofleet and other shoals. The diversion of the Port Clarence traffic to West Hartlepool had very much reduced the tonnage of the port, and the discovery of the ironstone in Cleveland, and the erection of the blast furnaces which immediately followed, tended still further to reduce the tonnage, inasmuch as a large proportion of the coals which had been shipped from Middlesbro' were now used in the smelting of iron; and the quantity of iron made was only sufficient at first to supply the wants of the neighbourhood. The tonnage of the port, therefore, from these causes continued to decline till the year ending October, 1855, in which year it was at the lowest, being only 290,658 tons. The very marked falling off in the tonnage of the port, and consequent decrease of revenue to the Commissioners, retarded the commencement of the intended works.

In 1855, the Commissioners determined, with the assistance of the Stockton and Darlington Railway Company, to proceed with the works, and, accordingly, in July of that year, operations were commenced at "Jack-in-the-Box" for the purpose of shutting up the north and middle channels, and guiding the whole of the tidal water through the south channel. The dredging of Cargofleet Scarp was at the same time commenced, and through this shoal, which had been a great obstruction to the navigation of the river, a channel was cut, 200 feet in breadth, and giving a depth of 7 feet at low water. The difficulty experienced by the Commissioners in obtaining money, with a revenue balance on the wrong

side, prevented the dredging and training works from being carried on so expeditiously as they otherwise would have been. They were, however, carried forward as the money could be obtained, and at such places as were most necessary; the rate at which they were constructed being increased as the revenue improved, and as the money became more easily attainable. *The channel as proposed by the Commissioners* has now been cut *through Cargofleet Scarp*, and they are still widening it. Nine miles of training walls have been completed, two and a half miles are now in progress, and there still remain other four miles to be constructed. In place of three channels, with an available depth of 1 foot 10 inches in the best, and so crooked that long steamers could not navigate any of them without leaving a deal of spare water under their keels, there is now a uniformly curved channel, with an available depth of 5 feet at low water spring tides. At the same time, the tonnage of the port for the past year, has increased to 525,452. Although, as already stated, the first effect of the jetties constructed between Newport and Middlesbro' no doubt was to straighten and confine the channel and deepen it to some extent; yet as the spaces between the jetties filled up, it was found that the channel began to deteriorate; new shoals began to form, and old ones get worse, so that in some places there was not 2 feet 6 inches at low water; and the foreshore had now silted up to such an extent as to be of little or no value as a tidal receptacle. Under these circumstances, the Commissioners resolved to apply to Parliament for reclamation powers, to enable them to derive benefit from the reclamation of these accretions. The money obtained from the sale of the lands to be applied in dredging and deepening the channel, and thus compensating for the loss of scouring powers. Since the obtaining of this Act (1858), 160 acres of silted-up foreshore between Haverton Hill and Port Clarence have been reclaimed. The greater portion of the foreshore between Newport and Middlesbro', similarly silted up, has already been sold for the erection of wharves for the accommodation of the various public works that are rapidly rising in the neighbourhood of the river, and will be of no less material service in improving the revenue of the port.

The Tees, as a general rule, has maintained a greater depth over its bar than any other river or harbour on the north-east coast; yet circumstances have operated in preventing mariners giving it the confidence which it deserves on running to it for the shelter which it is fitted to afford. These are, the varying depth and position of the channel, together with its situation in front of a low coast, with a long, broken

foreshore behind the bar. As already mentioned, the depth of water on the bar, in 1762, was 4 feet; during the last 20 years it has varied from 12 feet 6 inches to 3 feet at low water, spring tides. The average may be stated at 9 feet.

The bar travels regularly from east to north by west, and is in its most southerly position when the channel lies east and west. The gradual extension of the south gare forces the channel northwards, then the course out is about north by west; the current then cuts the south gare in two, when the north channel begins to fill up, until the east again becomes the navigable channel. The time occupied in travelling from point to point averages about 10 years. For two miles westward of the bar, the sea breaks, during storms, upon the low sandbanks on either side of the channel; and, from the overlapping of the gare, strangers are unable to detect any smooth water through which to navigate their vessels with safety. Even those well acquainted with the port frequently lose confidence, and prefer keeping the sea, or taking some other port, to entering the Tees when nothing can be seen but broken water; and when they may also be apprehensive of some change, for the worse, in the depth, or alteration in the direction of the channel. A long continuance of westerly winds, with high tides and fresh water, tend to lengthen out the gares and raise them in height. The current being then confined, until close upon the bar, has sufficient force to counteract the heaping up tendency of the wave. As the bar deepens the power of the wave to heap up is very much diminished; and, except for the moveable sand upon which the waves operate at high water, the depth could be easily maintained.

On the other hand, a long continuance of westerly winds carries the sand inwards, and flattens down the south gare; as it is lowered in height, the sea operates with proportionately increased force upon the north, which is lowered in its turn; the water, spreading over a much greater space, weakens the current, when, as a necessary consequence, the channel fills up, and the depth of water on the bar diminishes.

The great drawbacks to the safe and easy navigation of the Tees, so far as the entrance and lower portion of it are concerned, may be thus briefly enumerated:—the wide expanse on each side of the channel on which the sea is allowed to break, the shifting nature of the sandbanks, the varying depth of water on the bar, and the unprotected state of the lower reach of the river.

In the Tees Commissioners' Act of 1852, a clause was inserted, giving

the Lords Commissioners of the Admiralty power to construct a breakwater upon the north gare, and hopes were then entertained that Government would advance the money required for its construction. Mr. Calver, and the late Mr. Rendel, reported as to the exposed condition of the river entrance, and the means necessary for its protection and improvement. Its claims to aid were laid before the Select Committee of the House of Commons, and also before the Harbour of Refuge Commissioners. It was soon seen, however, that from neither of these quarters was any practical assistance likely to be derived; and thus, deprived of all extraneous help, the Commissioners resolved, if possible, to do the work themselves. From their commencement, in 1855, the low water training wall had been steadily extended towards the bar; the channel, in consequence, had been gradually but greatly improved, and the only remaining barrier to the safe and easy navigation of the river was caused by the state of the bar. In this bustling and progressive age, despatch is important even to sailing vessels, but for steamers it is indispensable; and the great increase in the number of the latter upon the river, made it plain to the Commissioners that they must commence the contemplated improvements without delay, if they wished to extend, or even retain, the existing traffic. Providence, it is said, helps those who help themselves, and when the designs of the Commissioners became known, the Stockton and Darlington Railway Company generously offered to carry material at a greatly reduced rate, while the ironmasters agreed to pay 2d. per ton for the removal of the slag, which will be largely employed in the present work. The payments, on the one hand, for the removal of the required material, and the reduction in the charge for carriage, on the other, will reduce the actual cost of the undertaking to one-third of the original estimate. Thus stimulated and encouraged, the Commissioners commenced operations, and the south gare breakwater has been in progress during the past summer. Four years, it is calculated, will be required for its completion. When sufficiently extended seaward as to afford shelter to the north gare, the Commissioners have in contemplation the construction of a north gare breakwater, which, in consequence of the protection then afforded, will be constructed much more easily and cheaply than if commenced with now. The training walls, still in progress, will require about 18 months to carry them as far as it would be safe or prudent to extend them until the breakwaters have been completed. Vigorous dredging in the channel, from Stockton to the sea, will be commenced with as soon as the training walls have, for the pre-

sent, been finished. When the works to which we have referred as being in progress, or in contemplation, shall be successfully terminated, the lateral channels, in which the flowing and ebbing tides waste their strength, will be shut up—the shifting sandbanks will be enclosed within permanent walls—the scouring power will be confined to the proper channel, when it will do its work in the right place and to the best advantage—the entrance will be unmistakeably pointed out by substantial landmarks on either side, between which, vessels may be run with confidence and perfect safety—the lower reaches of the river will be effectually sheltered, and the area of the anchoring pools will be greatly enlarged. Between the pier heads it is calculated that nearly 100,000,000 tons of water will pass every flow and ebb of the tide. This, it is expected, will be sufficient to scour the sand from the bar, leaving it with a depth of at least 14 feet at low water, or an average depth of 28 feet at high water, 20 feet to Middlesbro', and 18 to Stockton.

December, 1863.

NEWCASTLE-ON-TYNE: PRINTED BY A. REID, PRINTING COURT BUILDINGS, SIDE.